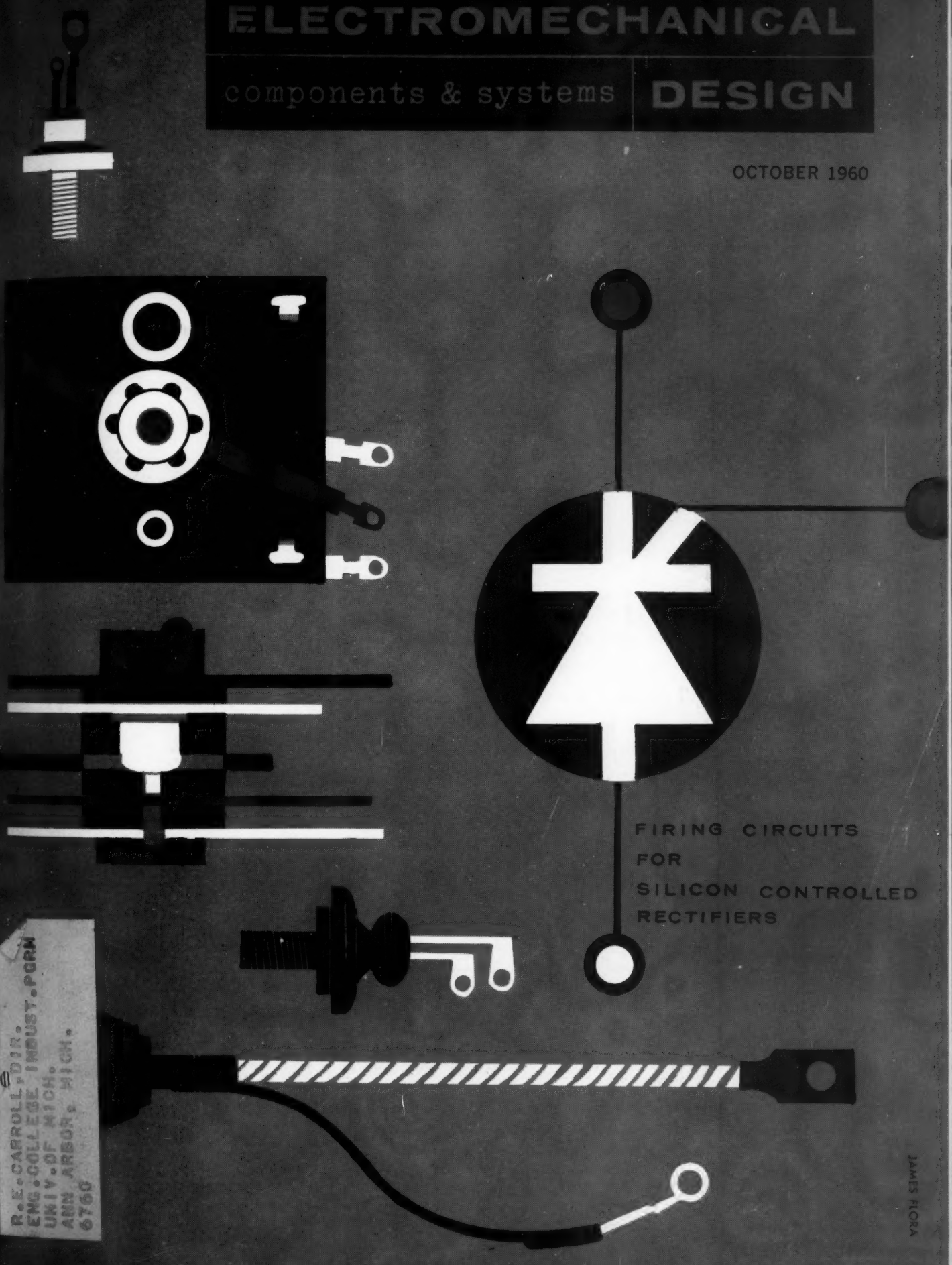
ELECTROMECHANICAL

components & systems DESIGN

OCTOBER 1960



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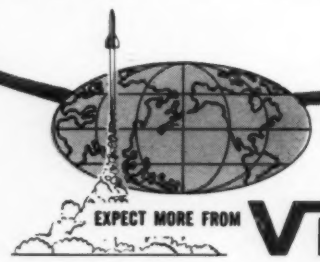

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OCTOBER 1960 • VOL. 4 NO. 10

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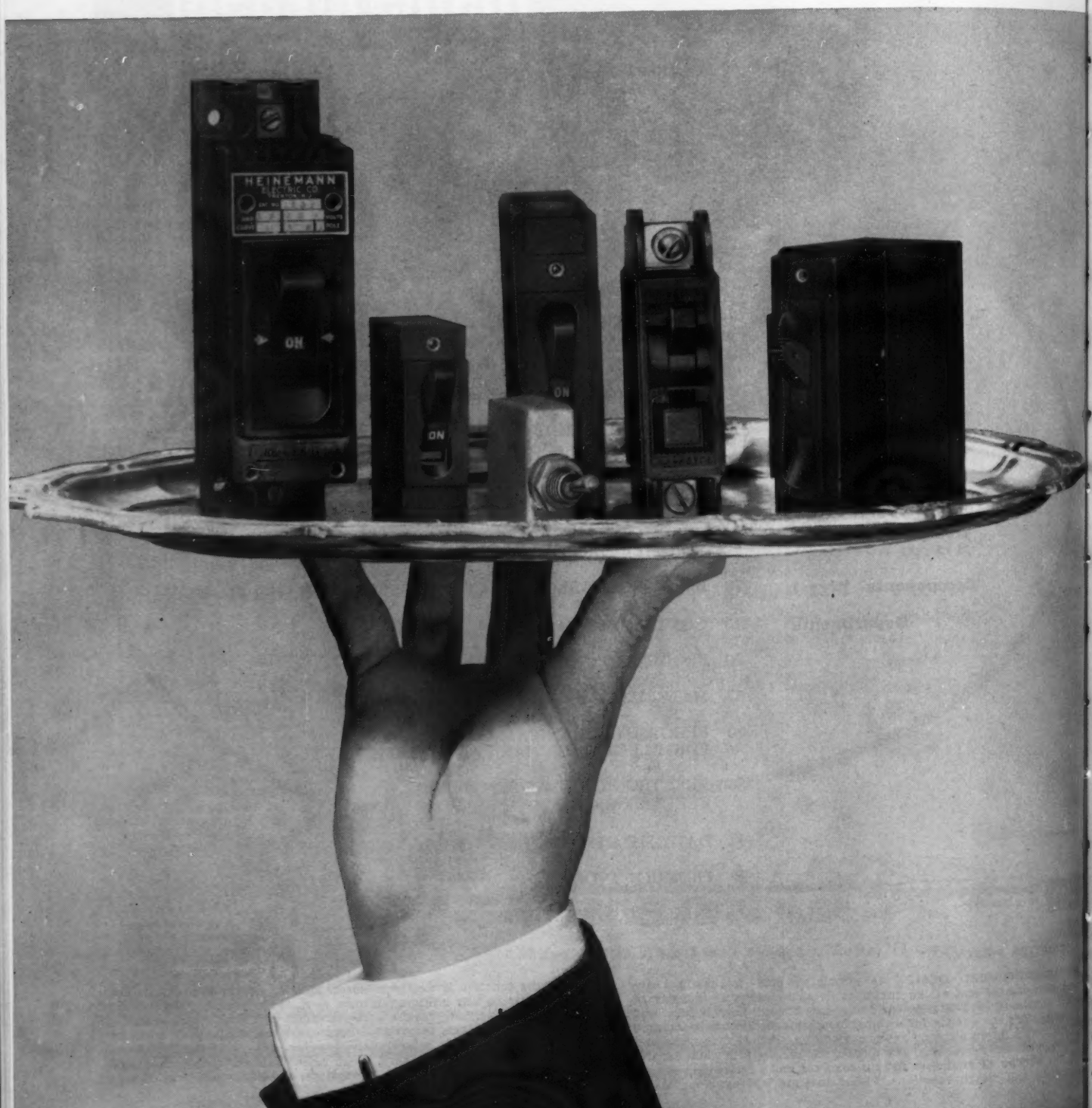

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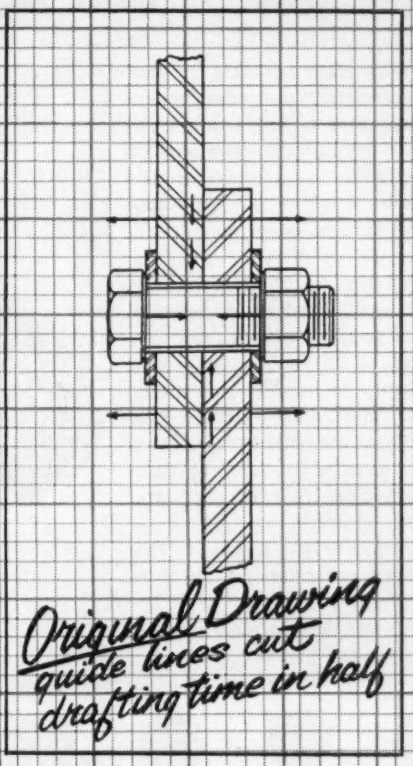

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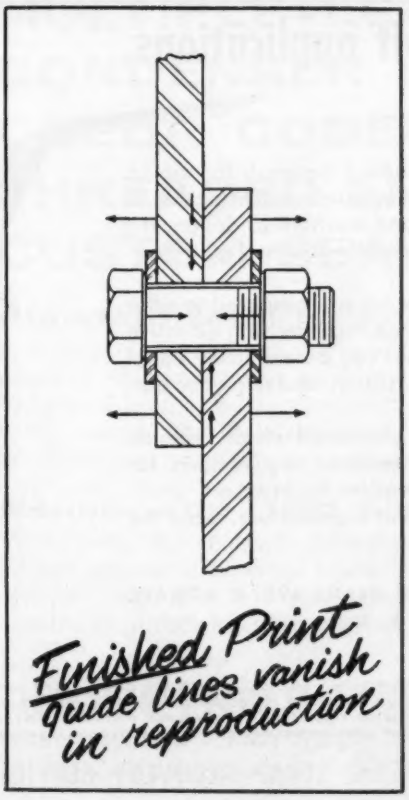

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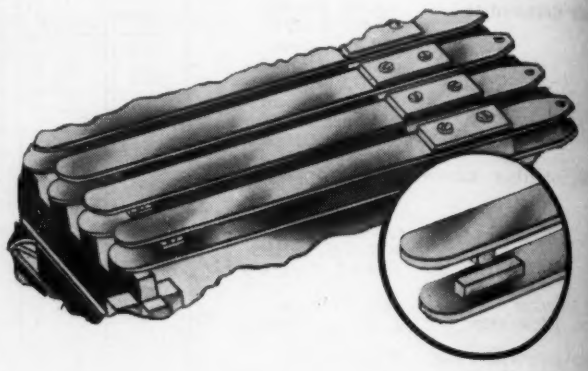

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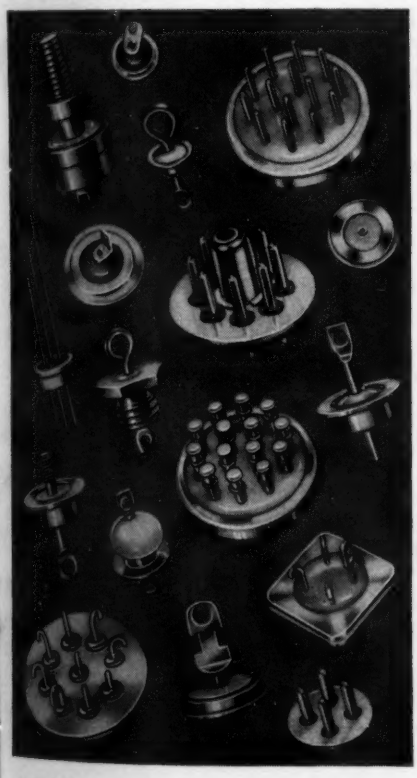

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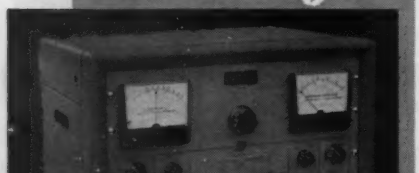

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CONTRACTS

Extreme-high-reliability capacitors for the Minuteman intercontinental ballistic missiles guidance system is the goal of General Electric's Electronic Specialty Capacitor Section, Irmo, S. C., A. E. Peltosalo, general manager, announced that a $600,000 contract calls for the development of solid electrolyte Tantalytic capacitors with a failure rate objective of 0.001 percent per 1,000 hrs., or better, and a similar contract for foil Tantalytic capacitors valued at $1,800,000. Mr. Peltosalo noted that General Electric's high reliability program would provide the entire industry with its "first significant measurement of the criteria, as well as the specifications for true reliability in tantalum electrolytic capacitors. It will generate a wealth of application information for capacitor users, too." Mr. Peltosalo explained that the dependability of capacitors is now largely due to exhaustive tests which manufacturers conduct on their finished products before they are sold. However, such performance testing assures only that the finished unit under test meets specifications at the time it is tested. GE believes that true reliability must be built into the product—it cannot be tested in. A highly automated integrated reliability data system will be a part of the program and vital to its success, Mr. Peltosalo added. It will collect detailed information on incoming materials, process control and test data. It will be the "alarm system" for the high reliability program, providing a quick feedback of information to signal when corrective action should be taken. The integrated data system under a reliability engineering control will store the complete history of each capacitor on a punched card, from the acceptance of its raw materials to the final performance and acceptance test results by quality control. A copy of this card will be shipped to the customer with each capacitor.

Integrated, cryogenic fueled power system incorporating secondary power reaction control and environmental control systems will be developed and tested by Kidde Aero-Space Div. of Walter Kidde and Co., Inc., Belleville, N. J., under a contract from Wright Air Development Div., U.S.A.F. An 18 month program will consist of two phases covering generalized study, design and development of a breadboard model. Phase 1, the parametric study, will begin by defining representative vehicle and environmental requirements in order to establish the necessary boundaries of the study. A detailed analysis will be made to establish the optimum integrated system. Study and feasibility testing will be conducted in the following areas: secondary power, tankage, equipment and crew environmental control, reaction control and integrated overall system control. Following the study and feasibility testing of the sub-systems component, specs and test procedures will be written. Phase II will establish the feasibility of the integrated system, employing all new concepts. Testing of the breadboard will demonstrate the integration of the sub-systems, and establish experimentally their dynamic response characteristics.

"Silent Sentry" radar units may replace the soldier's traditional "Who goes there?". Sperry Gyroscope Co., Great Neck, N.Y., under a $3.2 million contract, will develop these highly mobile radar units that reveal movements of tanks, trucks or troops. The movements are translated into identifiable sounds in head sets worn by soldier operators. Using these "electronic ears", an operator can pick out and pinpoint target movements within a 3 mile area. Rugged and light, the radar provides range, azimuth and elevation data with an accuracy of better than 25 yards. So sensitive, it can detect the difference between a walking and a running man and will spot a lone man walking as much as a half mile away.

CONTRACTS *(continued)*

Vehicle engine and electrical system analyzing equipment will be designed by the Allen B. DuMont Labs, Div. of Fairchild Camera and Instr. Corp., Clifton, N.J. under contracts totaling $121,000 from Army Ordnance. Two types of equipment are involved in the development work. One will be "multifuel engine electronic diagnostic equipment", probably an oscilloscope type of analyzer similar to the commercial DuMont EnginScope. However, the new analyzer will be applicable to diesel and other type engines as well as to conventional engines with ignition system. In addition to almost instantaneous check of ignition systems and parts, the equipment is intended to quickly check for malfunctions in nozzle, fuel line, pump and other segments of various injection systems. The second development will be portable vehicular electrical test equipment which is intended to militarize, miniaturize, and consolidate diverse electrical testing apparatus.

Briefly:

Re-entry heat shield: $967,000 to Avco Corp., Wilmington, Mass., from Lockheed Air. Corp.

Helium regulators: $1.5 million to Aero. and Instr. Div. of Robertshaw-Fulton Control Co., Anaheim, Calif., for U.S.A.F. Titan ICBM.

Communication and radar test equipment: $1,165,000 to Specialty Electronics Div. Corp., Syosset, N.Y., from U.S. Army

Hi-voltage power supplies: $60,000 to Kinetics Corp., Solana Beach, Calif., from Bendix Corp., Towson, Md.

Electronic checkout equipment: $1.2 million to Hughes Aircraft Co., Culver City, Calf., from Martin Co., Denver, Colo., for Titan ICBM.

High frequency communications: $850,000 to Manson Labs, Inc., Stamford, Conn., from Navy Bureau of Ships.

Airborne identification coding equipment: $800,000 to Telecomputing Corp., L.A., Calif., from the Air Force.

Radar electronic scanning techniques: $91,000 to Microwave Associates, Burlington, Mass., from the U.S. Navy.

Airborne electronic countermeasure equipment: $300,000 to HRB-Singer, Inc., a unit of the Military Products Div. of the Singer Mfg. Co., State College, Penna., from the U.S.A.F.

Anti-submarine rocket (ASROC) missile: $2.9 million to the Ordnance Div. of Minneapolis-Honeywell Reg. Co., Hopkins, Minn., and Durante, Calif., from the Bureau of Naval Weapons.

Inertial navigation equipment: $400,000 to Bell Aerosystems Co., Buffalo, N.Y. from the U.S.A.F.

High reliability transformers: $429,930 to Wheeler Electronics Corp., Waterbury, Conn., from Autonetics, Div. of N.A.A.

Countermeasures simulation system: $241,000 to Electro-Pulse, Inc., Subsid. of Servo Corp. of America, Culver City, Calif., from the U.S., Navy.

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YS BLOWERS

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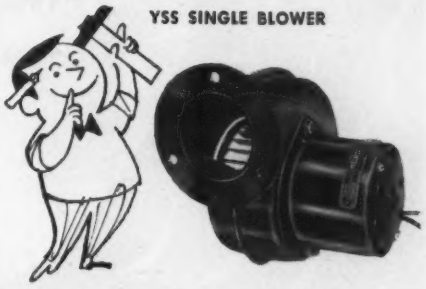

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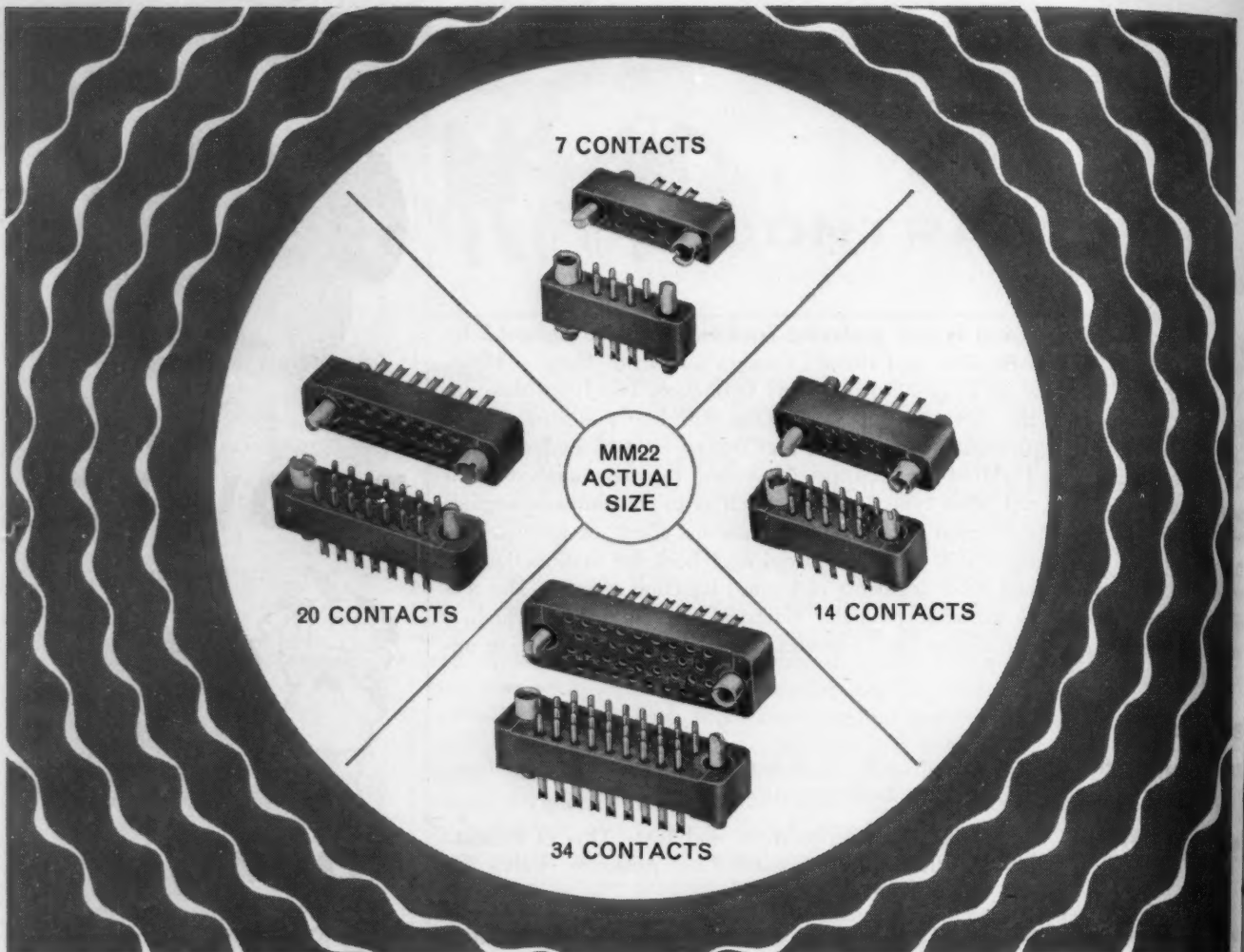

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Contacts, Center-to-Center	3/32"
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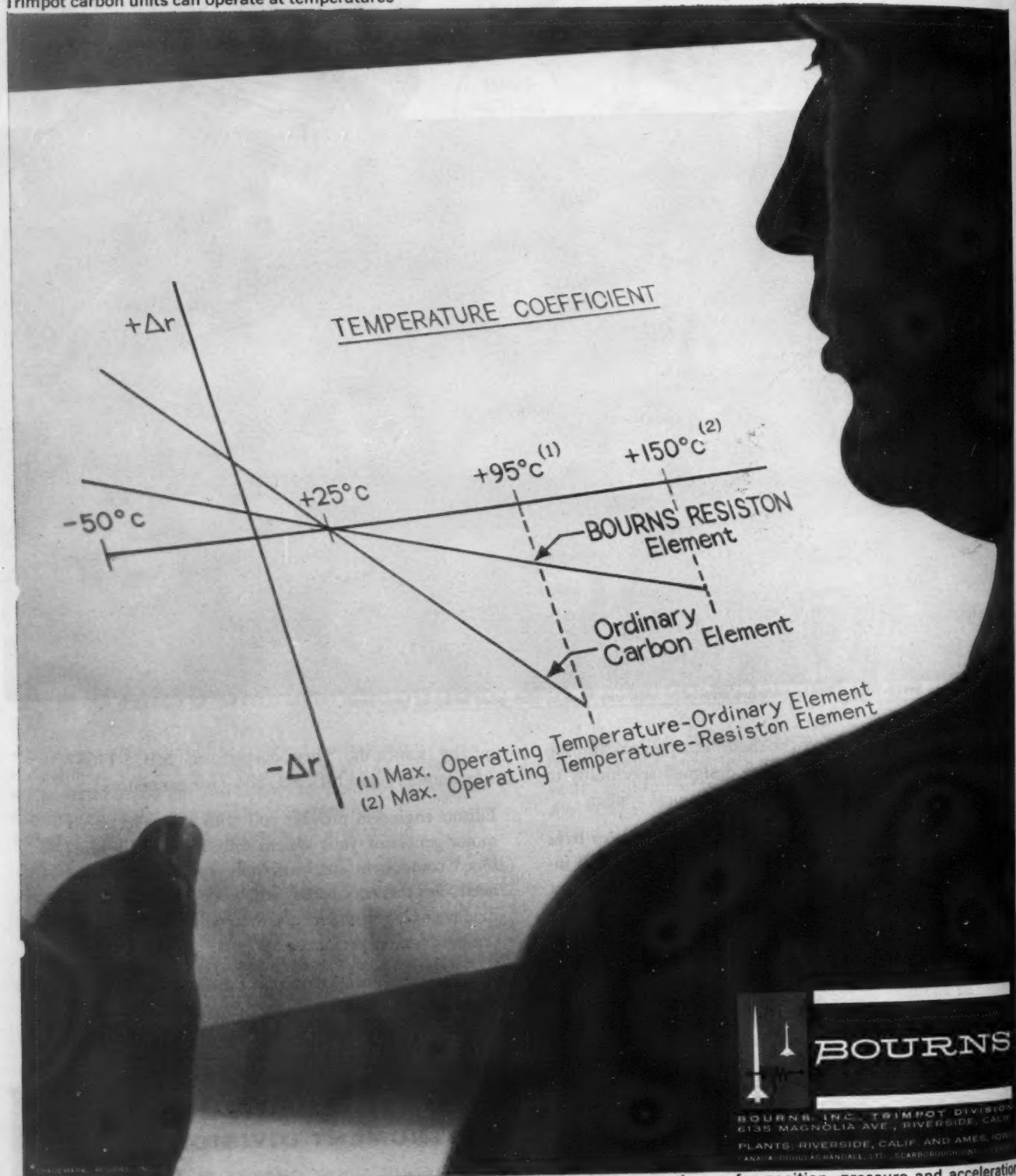

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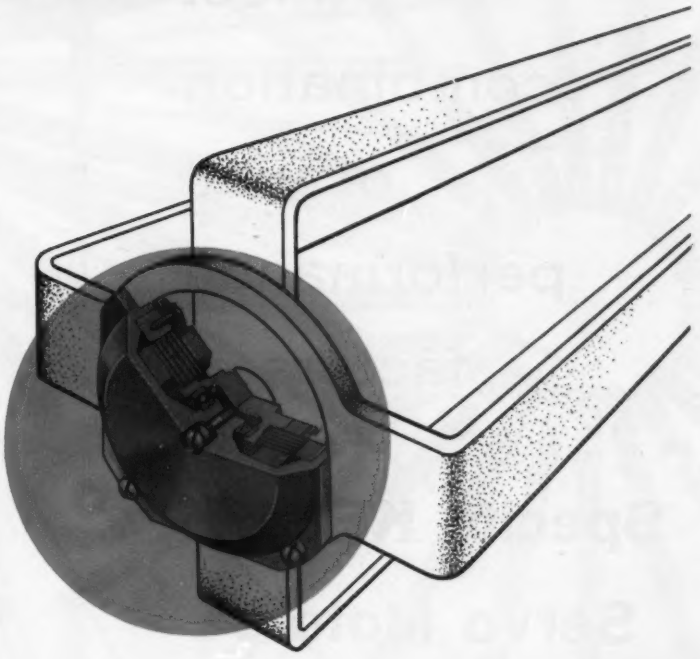
Inland has achieved this compact pancake shape while maintaining the low-power input to high-torque output ratio of a d-c torquer.



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COMPARE THESE RATINGS WITH A TYPICAL SERVO MOTOR-GEAR TRAIN COMBINATION

	T-2136-A	T-2136-B	T-2136-D
Peak torque, oz. in.	35	35	35
Volts at peak torque, stalled at 25°C	26.0	20.6	33.5
Amps at peak torque	1.6	2.0	1.3
Total friction, oz. in.	0.8	0.8	0.8
Rotor Inertia, oz. in. sec^2	.007	.007	.007
Weight, oz.	9	9	9
Dimensions (inches):			
O.D.	2.81	2.81	2.81
I.D.	1.00	1.00	1.00
Thickness	.63	.63	.63

For complete data on these or other Inland d-c pancake torquers, address Dept. EL, Inland Motor Corporation of Virginia, Northampton, Massachusetts.

INLAND MOTOR CORPORATION OF VIRGINIA

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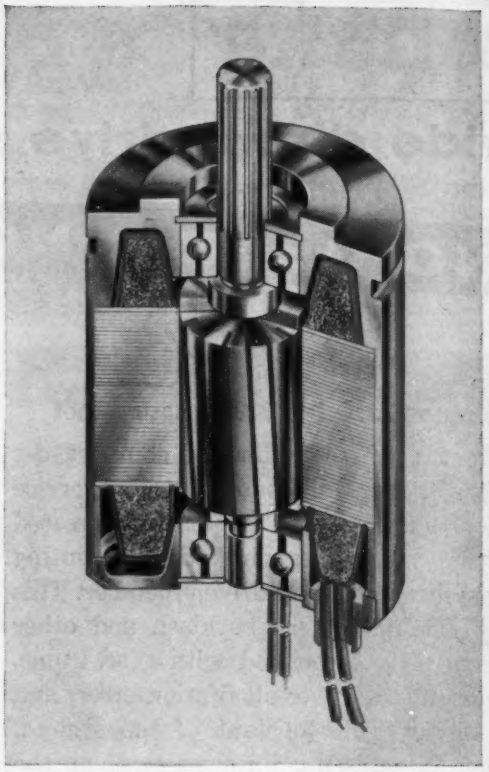

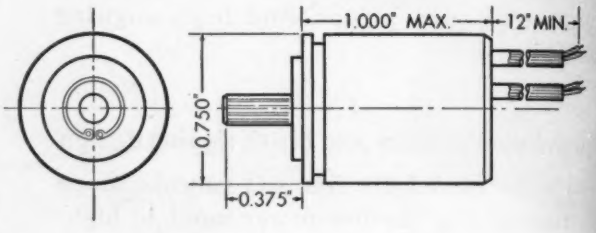

Performance and reliability in the size 8 servo motor, for example, is underscored by:

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- High acceleration at stall.
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- Superior "white room" manufacturing, assembly and inspection techniques.

TYPICAL PERFORMANCE CHARACTERISTICS

Type Number	008E2A	008E2C	008E2D
Excitation Frequency (cps)	400	400	400
Rated Voltage:			
Fixed phase (volts)	26	26	26
Control phase (volts)	26	40/20	26
Input Power at Stall (watts)	1.75	1.75	2.50
Starting Voltage (volts)	0.68	1.0	0.68
Stall Torque (oz. -in.)	0.22	0.22	0.30
Ratio Stall Torque to Total Power Input	0.060	0.060	0.060
Rotor Inertia (gm. cm^2)	.414	.414	.414
Acceleration at Stall (rad./$sec.^2$)	36,000	36,000	53,000
No Load Speed (rpm)	6,500	6,500	6,500
Temperature Rise at Stall (°C)	50	50	60
Operating Temperature Range (°C)	−55 to +125	−55 to +125	−55 to +125

For more information on these or any other of the complete line of Ketay Servo Motors and/or motor generators from size 08 to size 23, 26 or 115 volt, 400 or 60 cycle excitation, please write.

NORDEN

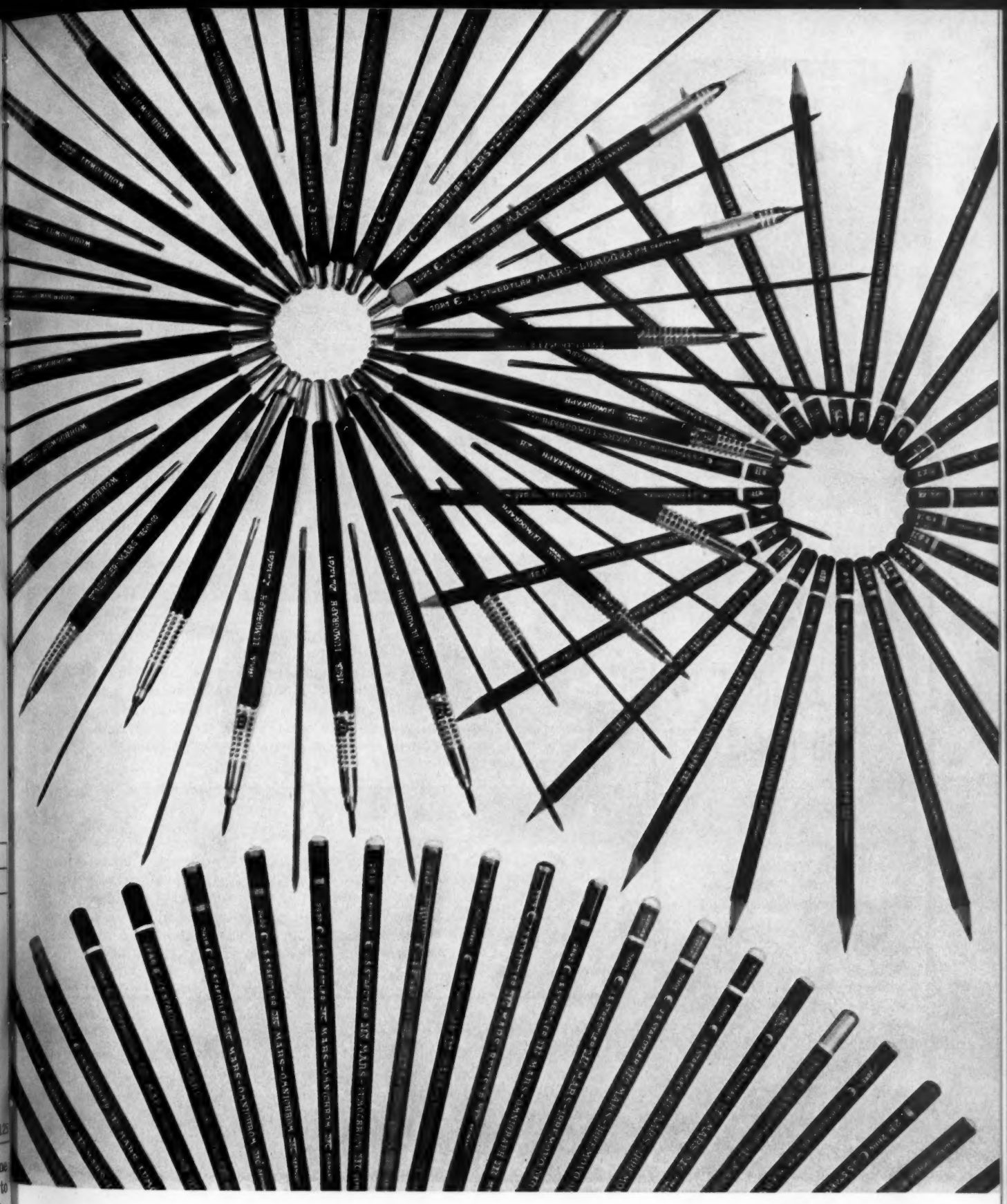
KETAY DEPARTMENT

NORDEN DIVISION

UNITED AIRCRAFT CORPORATION

COMMACK, LONG ISLAND, NEW YORK

CIRCLE NO. 16 ON INQUIRY CARD



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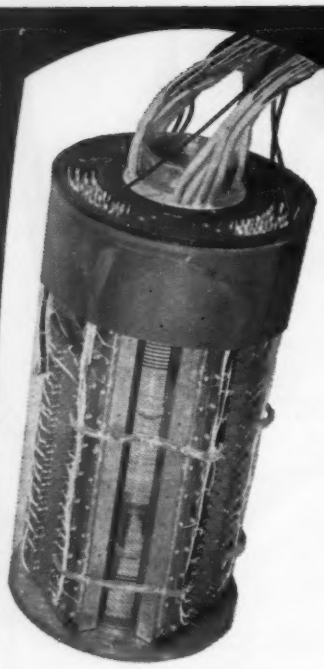

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For complete information, write:

SLIP RING COMPANY of AMERICA

3612 West Jefferson Blvd., Los Angeles 16, Calif.

CIRCLE NO. 18 ON INQUIRY CARD

PRODUCTION AIDS

If you want more information on the production aids discussed below write the appropriate number on the reader service card.

COMPONENT HOLDERS 435

A newly designed series of spring-molded component holders eliminate the possibility of shearing component leads. Designed by Jupiter Electronics, the component holders are normally used in labs or in model shops for prototype assembly work and for quick set-ups for checkout of semi-conductor circuit designs. Single pressure of five to seven and one half pounds opens the jaws of the glass holders for the insertion of leads as large as banana plugs.

CIRCUIT BOARD DRILL 436

Holes from 0.020 to 0.250 inches in diameter can be drilled in circuit boards at the rate of 64,000 holes per shift with a new machine developed by Nawide Machine Tools, Div. of Nationwide Engineering Service, Inc. The tool can be within 0.001 inches of true position and minimum wall thickness between holes is 0.004 inches. Circuit boards can be drilled individually or a stack of five at the same time. The machine features a woodpecker action that cleans out the chips as it goes, producing no burrs and requiring no delamination since the clamping pressure of the stock board is applied directly over the drill area.

ULTRASONIC IMPACT GRINDER 437

Designed for precision machining operations and the manufacture of semiconductor and other electronic devices, a new, faster operating, ultrasonic impact grinder machines areas up to one and three eights inches in diameter. Featuring the first air cooled, 300-watt magnetostrictive transducer in a machine tool, the Raytheon Model 2-333 eliminates bothersome plumbing arrangements generally associated with liquid-cooled units. The magnetostrictive transducer provides continuous operation, eliminating down time for cooling often necessary with ceramic transducers.

WORK-HOLDING FIXTURES 438

Eight page catalog describes a variety of vises, card holders, harness board holders, work positioners, bench and form model chassis holders and complete modular production assembly systems. Flotron Industries, Inc.

AXIAL LEAD MARKER 439

Axial lead components can be marked with text and polarity markings in accordance with JAN specifications at the minimum rate of 2600 per hour. Markem's Model 146A machine has been designed for marking diodes, capacitors, resistors and other axial lead components with curves or irregular surfaces. Machine is 18 x 11 x 12 inches and can be mounted on a table or belt.

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Small, self-contained, inexpensive high speed machine meters, mixes and dispenses two component plastic systems such as epoxies. Available from New Plastic Corp., Los Angeles, Calif.

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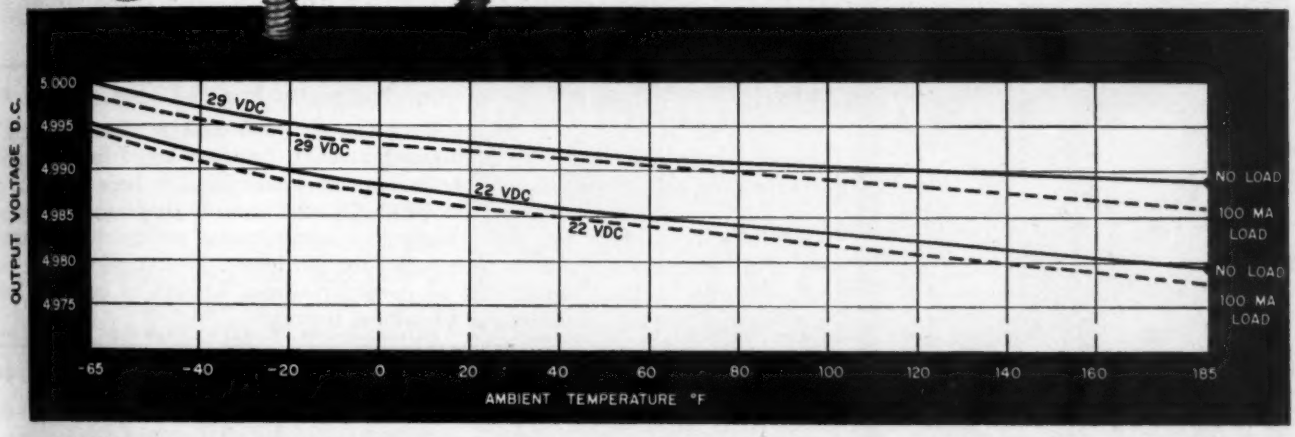
ACTUAL SIZE

Compact, low-voltage, low-current reference power supply for airborne telemetering transducer circuits.

Assures highly stable voltage regardless of input and load variances over a wide operating temperature range.

Regulator incorporates minimum number of components to achieve optimum performance, highest reliability.



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Output	4.975 to 5.000 Volts D.C. under all conditions of line load, and temperature variations
Load	0 to 100 milliamps
Output Ripple	30 millivolts peak-to-peak under input transient conditions
Ambient Temperature Range	—65°F. to +185°F. (can be furnished to 212°F.)
Altitude	100,000 feet
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Weight	5 ounces

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Please send me more information on the Văp-Air 5-Volt D.C. Power Supplys.

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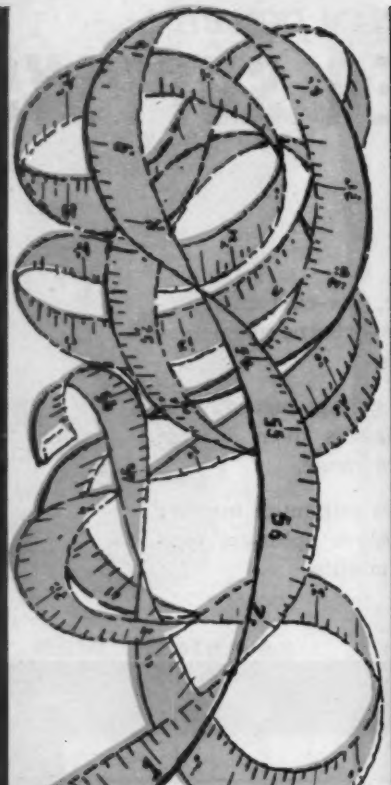
CIRCLE NO. 19 ON INQUIRY CARD



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CIRCLE NO. 20 ON INQUIRY CARD

PRODUCTION AIDS (Continued)

HITEMP VACUUM FURNACE 442

A new hi temperature vacuum furnace featuring what is believed to be the smallest hot-zone in commercial equipment is marketed by the Vacuum Furnace Division of Richard D. Brew & Co. Inc., Concord, N.H. The furnaces are resistance units that perform operations such as braizing, bright annealing and melting at vacuum pressures of 0.1 to 0.05 micron Hg at uniform temperatures up to 2500C (4532 F). Five kilowatts of power are required for continuous operation at maximum temperature. The unusually small hot-zone measures 1" by 3" and is particularly geared for the laboratory and the prototype production.

PRODUCTION TESTING 444

Giannini Controls Corp. of Duarte, Calif. has a new production testing technique that eliminates the need for time consuming calculations from quantitative test data readout. The new system uses a simple instrument servo to provide both go and no-go indication and quantitative readout in the form of percent deviation from established nominal values relating to each test performed on the item under test. The instrument servo is an error indicator, imposing less stringent accuracy requirements from those usually associated with instruments providing direct reading absolute quantitative values. Because it can be programmed, the unit covers a wide range of test parameters and accuracies without requiring physical adjustment of the best equipment.

LEAD FORMER 445

Federal Manufacturing & Engineering Corp.'s New Design Tool Co. Div. is manufacturing an automatic high-speed cutting, bending and forming machine for resistor and diode leads. Low in cost, the machine has been designed for the preparation of components for printed circuit boards. It features an adjustable card feed chute for rapid loading of components, stellite dipped cutters, adjustable speeds and an air filter regulator lubricator. It accepts different sizes of resistor and diode bodies and all carded resistors. Length of cuts and bends can be quickly adjusted without additional tooling.

PRODUCTION TEST COMPUTER 446

Thompson-Ramo-Wooldridge Products Co. is marketing a RW-300 digital control computer for production testing. For example in the production testing of potentiometers, production parts are compared with a standard part and the results are computed and printed out on an automatic typewriter. The production testing system can perform any series of test routines programmed into its memory, collect and process all data and provide meaningfull printed results. In a typical test setup, the computer continually monitors the test station and begins the test when the operator throws the switch at the station. The computer also prints out a complete record of the test, including calibration tables, computed values and reasons for rejection. If time is not available for print-out between tests, the computer can store all the data on magnetic tape and print it out at a more convenient time. In addition to production testing, the company states that the computer has many applications in the petroleum, chemical, primary metals, electric power, nuclear, aircraft and missile industries.

BALL AND ROLLER BEARING ANALYZER 44

Want to know how serviceable ball and roller bearings are in 30 seconds? Bearing Inspection Inc. has a machine that analyzes the vibrations produced by a rotating bearing and indicates unserviceable bearings both visually and audibly by means of a meter, C.R.T. display and a loud speaker. Instrument requires 18" x 20" bench space and is designed to handle bearings from ⅜" to 10" O.D.

WAFER SLICER 44

Embodying a new concept in slicing friable matrials, the I/D Micro-Slicer by DoAll Co., Des Plaines, Ill., uses a thin cutting wheel that has an open center resembling a doughnut. Circling the inside opening of the wheel is a diamond cutting edge. The ingot of metal to be cut cut is positioned through the inner opening of the wheel. Metal ingots, such as germanium, are automatically sliced into wafers one one-hundredth of an in. thick in production of transistors and other components used in Electronic equipment. According to DoAll, the tool will increase productivity up to 50% in cutting rare and expensive metals.

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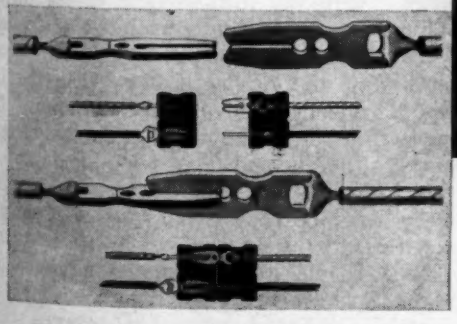

Photo shows Elco's patented Varicon Connectors and unique fork-like contact plated with Sel-Rex Bright Gold.

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CIRCLE NO. 21 ON INQUIRY CARD

NATURAL FREQUENCY AND PHASE RELATIONS IN A DRIVEN SEISMIC SYSTEM

by E.F. Kiernan, Instrumentation Design Specialist, Los Angeles, California

Vibration measurements at the present time generally utilize a pick-up which incorporates a seismic system as part of the transduction. The readout of the pick-up signal may be calibrated in terms of acceleration, velocity, or displacement depending on the relation between the frequency range over which the pick-up is used and the natural frequency of the seismic system. The natural frequency of the seismic system is a highly pertinent parameter which can be determined with adequate precision. It should be noted that no actual physical system ever oscillates at its natural frequency under average ambient temperature conditions. Molecular, viscous, or coulomb damping are always present either singularly or in combination. Discussion of ambiguous terms such as 'damped natural frequency' and 'undamped natural frequency' only adds to the confusion.

Despite the large amount of published material regarding vibration parameters, there is a distinct lack of understanding as to what actually happens in a driven seismic system. A considerable portion of the fault lies in the use of terminology which has not been standardized. For use in this discussion, the following definitions are listed:

Natural Frequency. That frequency at which a device or system would tend to oscillate, if the damping were reduced to zero.

Resonant Frequency

(1) Amplitude resonance; exists when a change in frequency of a constant amplitude driving force produces a decrease in amplitude of the displacement in a driven system.

(2) Natural resonance; occurs when the frequency of the driving force is the same as the natural frequency of the driven system. (Note: there is no amplitude resonance at this frequency).

Damping. The forces acting on an oscillatory system to reduce the amplitude of oscillation.

Critical Damping. That amount of damping which is just sufficient to convert an oscillatory system to a non-oscillatory system.

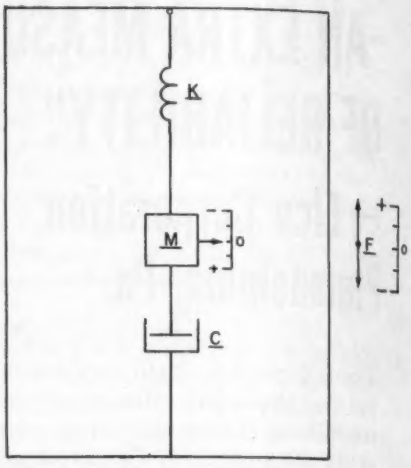
Seismic System. A combination of inertia, elasticity, and damping utilized as part of the transduction in vibration transducers.

Transduction. The principle by which a transducer operates.

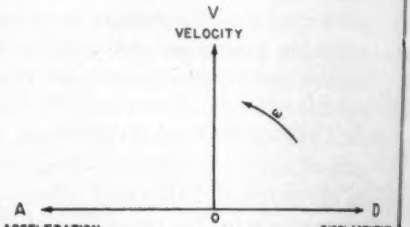
Transducer (sensor, pick-up, probe, etc.). A device which responds to a physical phenomenon and produces a signal which is a function of one or more characteristics of the phenomenon.

Consider a simple seismic system composed of an elastically suspended mass subjected to viscous damping and constrained to motion to and fro along a single axis (Fig. 1). If the system is subjected to excitation by a sinusoidal force, F, acting along the axis as shown, the mass will execute sinusoidal motion. The phase relationships between displacement, acceleration, and velocity of the driving force are indicated in Fig 2. As shown, the velocity leads the displacement by 90°, and the acceleration leads the displacement by 180°: As long as the motion remains sinusoidal, these phase relations remain fixed. As long as the amplitude of the driving force does not exceed a value above which the seismic system will no longer execute sinusoidal motion, the displacement, velocity, and acceleration of the *seismic* system also have the phase relations shown in Fig 2.

We now have two sets of parameters, containing displacement, velocity, and acceleration. One set relates to the driving force, the other to the driven seismic system. How do the parameters of each set relate to each other phase (or time) wise? Three situations will be discussed. These situations hold regardless of the damping in the seismic system. The three situations have to do with the ratio of the frequency of the driving force to the *natural* frequency of the seismic system; (1) when the ratio approaches zero, (2) when the ratio equals one, and (3) when the ratio approaches infinity. Fig. 3, illustrates graphically these relationships. In Fig 3a, the respective displacements, velocities and accelerations are in phase. As the f/fn ratio increases, the seismic system lags behind the driving force until at the ratio f/fn =



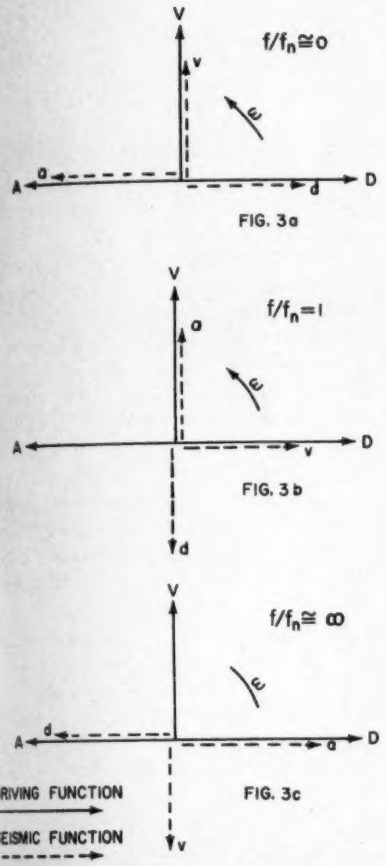
A simple seismic system composed of an elastically suspended mass subjected to vicous damping and constrained to motion to and fro and along a single axis.



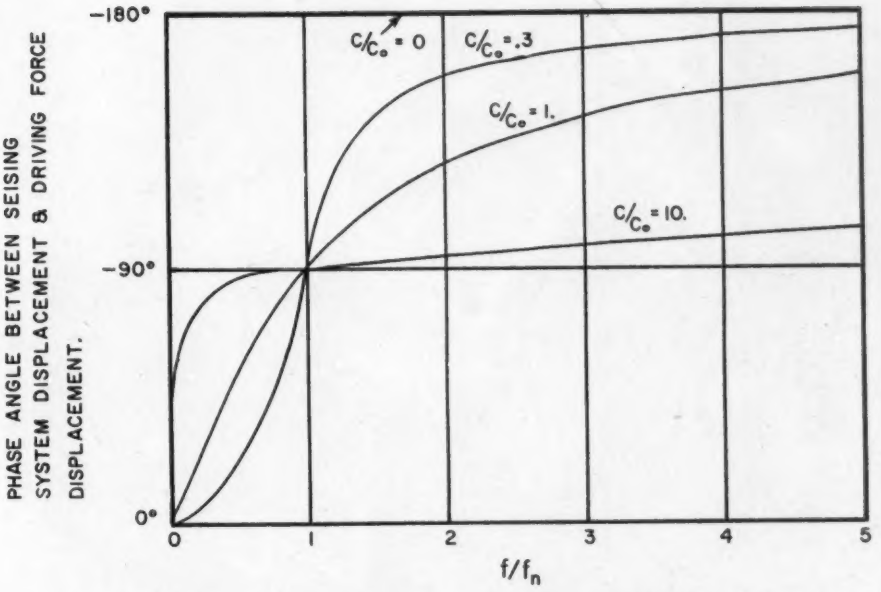
Phase relationships between displacement, acceleration and velocity of the driving force.

1 the seismic displacement is 90° behind the displacement (or amplitude) of the driving force. This places the velocity of the seismic system in phase with the displacement of the driving force, and the acceleration of the seismic system in phase with the velocity of the driving force. When the frequency ratio approaches infinity, the displacement of the seismic system is 180° behind the driving force displacement, the seismic system velocity is 90° behind the driving force displacement and the seismic system acceleration is in phase with the driving force displacement.

What happens in between these ratio values? Fig 4, indicates the phase relation of the seismic system displacement and the displacement (amplitude) of the driving force for a range of values for f/fn and three ratios of the actual damping in the seismic system to the critical value C_0.



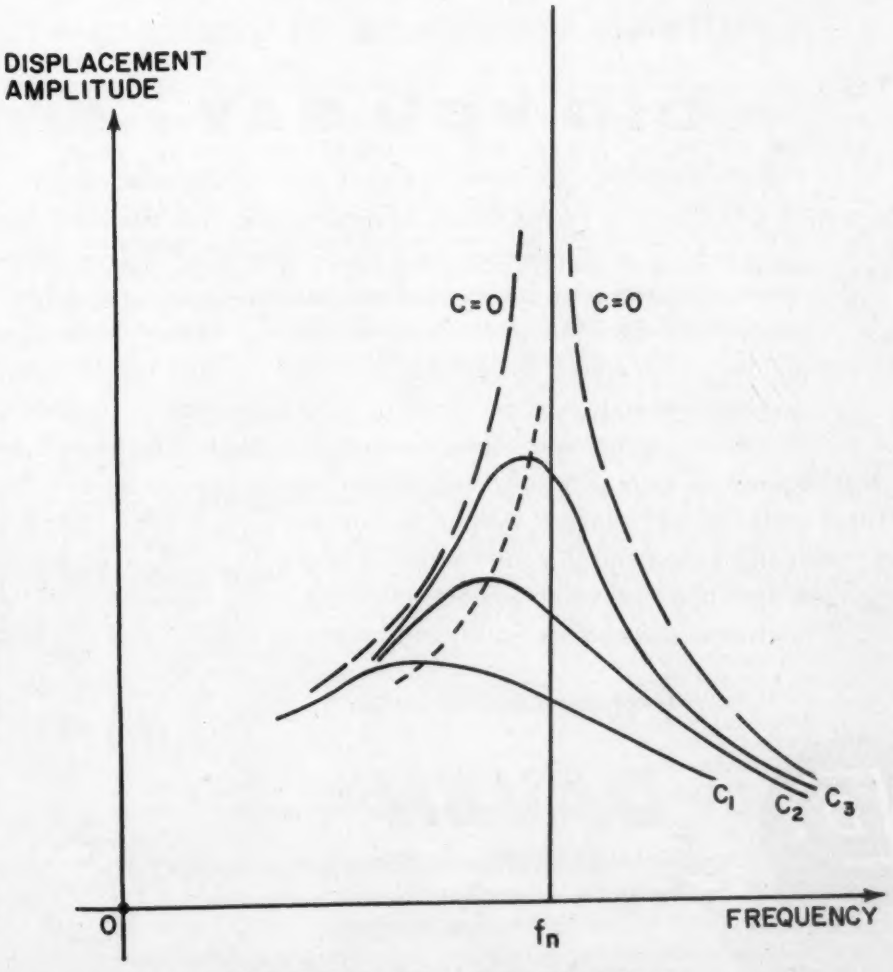
Relations between displacement, velocity and acceleration of a driven seismic system and the same parameters of the driving force, for three values of the ratio of the frequency of the driving force to the natural frequency of the seismic system.



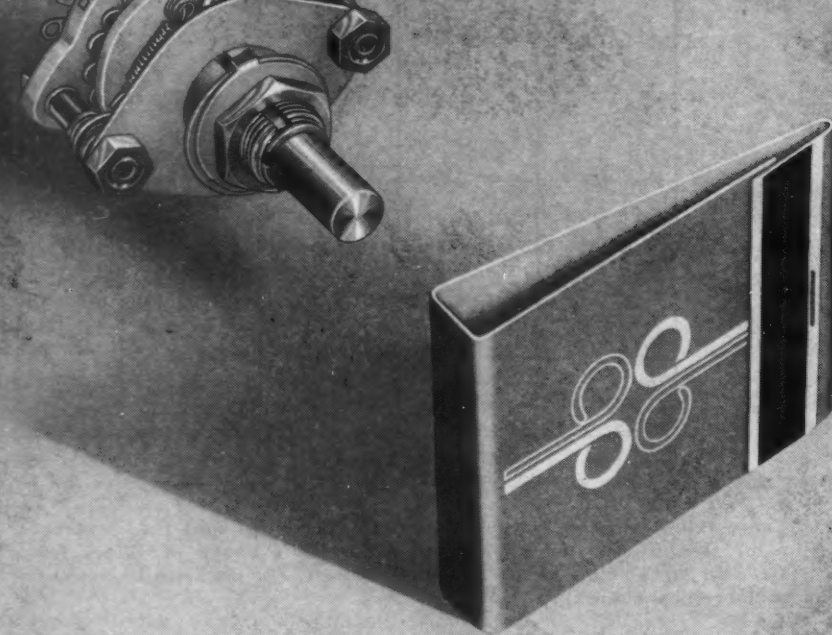
Phase relation of the seismic system displacement and the displacement (amplitude) of the driving force, for a range of values for f/f_n and three ratios of the actual damping C (in the seismic system) to the critical value C_o.

What about resonance phenomena in seismic systems? Two conditions of resonance have been defined; amplitude, and natural. It should be noted that amplitude resonance does not coincide frequency wise with the natural frequency of the seismic system, in practical applied engineering. Amplitude resonance takes place below the natural frequency as shown in Fig 5. As the damping is increased, the peak amplitude occurs at lower and lower frequencies. While at the same time the height of the peak lessens and becomes broader. With heavy damping, no peak is in evidence.

Natural resonance takes place when the seismic system is driven at its natural frequency. At this frequency, the seismic system displacement is exactly 90° out of phase with the displacement of the driving force (Fig 4).



Resonance phenomena in seismic systems.



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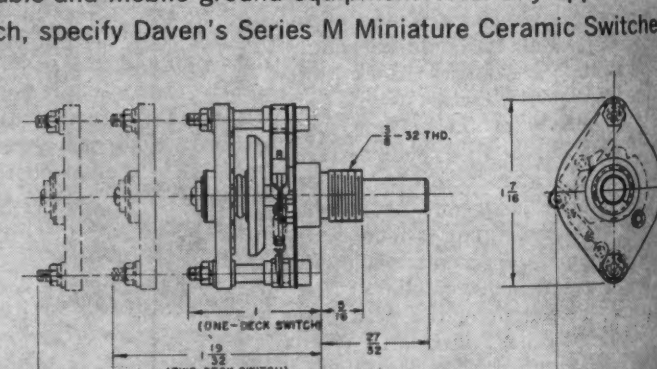

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Also, as shown in Fig. 3b., the acceleration of the seismic system is in phase with the velocity of the driving force. This situation makes it very convenient to determine the natural frequency of an accelerometer. The equipment needed includes a shaker provided with a velocity coil and an oscilloscope having the same phase shift in the vertical and horizontal amplifiers. With the accelerometer mounted on the shake table, signals from the accelerometer and the velocity coil are fed to the two sets of deflection plates in the oscilloscope. The shake table frequency is adjusted to present a straight line pattern on the screen of the scope at the resonant frequency. If the raster on the scope has been properly calibrated, the damping factor can be determined at the same time provided the damping is not too high in value.

Finally, it can be said that seismic pick-ups are used as accelerometers below their natural frequency and as displacement or velocity pick-ups above their natural frequency. The output of a displacement pick-up is differentiated to obtain velocity information. • • •

Ground Support Tester

For use in performance testing and analyzing electronic circuitry malfunctions in power supplies for missile and aircraft weapons systems, a test system is said to have maximum simplicity of operation. The equipment is composed of two packages, power supply and test console. The power unit not only supplies the necessary voltage to operate the test console but also provides the load for dynamic tests of speed regulators, ac voltage regulators and dc regulated supplies. The test console contains the load bank as well as actual test circuitry and instrumentation and can test and adjust complete power panels, sub panels and individual components. By using a given switching sequence, static or open loop gain of each amplifier stage, as well as the overall system can be checked. If the panel meets the open loop requirements, additional switching operations permit closed loop performance tests to be run. Reactors, diodes and transistors can be checked by discontinuing them from their circuits and attaching clip leads. American Electronics, Inc., El Monte, Calif.

Write No. 617 in Box on Inquiry Card
←CIRCLE NO. 22 ON INQUIRY CARD

The new 20 watt DIEHL† Instrument Servomotor a study in practical design

A carefully constructed winding—set in a round, die cast aluminum housing and totally encapsulated with a protective epoxy resin . . . a low inertia ingot-iron rotor . . . and two sets of prelubricated ball bearings . . . a simple anatomy. Yet these few simple parts combine to make the new 20 watt DIEHL Instrument Servomotor the most practical servomotor ever designed for commercial applications . . . because all costly construction features and environmental precautions which are unwarranted in a commercial application have been eliminated. But full performance and all essential environmental precautions have been retained . . . including moisture, salt, and fungus proofing, good resistance to shock, safe operation in ambients of −55 to +55°C, and these other outstanding performance characteristics:

SPECIFICATIONS AT STALL

Cat. No.	FPE49L-116-1
Output	20 Watts
Voltage (per phase)	115 Volts
Frequency	60 Cycles
Torque	25 oz. in.
Input power (per phase)	54 watts
Control phase impedance	174 ohms
No Load Speed	3500 R.P.M.
Inertia (Wk2)	.725 oz. in.^{2}
Theor. acceleration	13,300 rad/sec.^{2}
Weight	2.75 lbs.
Motor Transfer Function	$\frac{3.2}{S\ (.028S + 1}$
Frequency response	5.75 cyc./sec

Write for more information on our complete line of instrument servomotors. Available in sizes 11 and 15, power ratings from 1 to 20 watts.

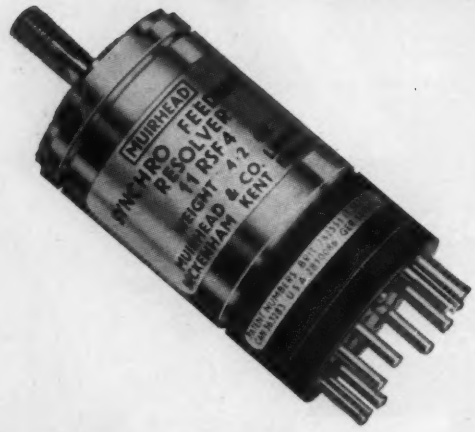
Diehl†
DIEHL MANUFACTURING COMPANY
A SUBSIDIARY OF THE SINGER MANUFACTURING COMPANY
Somerville, New Jersey

SINGER*
MILITARY PRODUCTS DIVISION

†A Trademark of THE DIEHL MANUFACTURING COMPANY *A Trademark of THE SINGER MANUFACTURING COMPANY

CIRCLE NO. 23 ON INQUIRY CARD

A REVOLUTION IN RESOLUTION



THE MUIRHEAD SIZE II COMPENSATED RESOLVER

Functional Accuracy better than 0·05%!!

The MUIRHEAD range of Computing Resolvers—Compensated Resolvers—and Sweep Resolvers, includes:

11M6C1	Size 11	Resolver
11RSF4	Size 11	Compensated Resolver
15M6A1	Size 15	Resolver
15RSF4	Size 15	Compensated Resolver
18M6A1	Size 18	Resolver Transmitter
23M6B1	Size 23	Resistor Compensated Resolver
23RS4a	Size 23	Resolver
23M7C1	Size 23	Compensated Resolver
23M7A1	Size 23	Sweep Resolver

and many others

Full details available on request

MUIRHEAD

Precision Electrical Instruments

MUIRHEAD INSTRUMENTS INC.,
441 Lexington Avenue, New York 17, N.Y., U.S.A.
Telephone: Murray Hill 2-8131

MUIRHEAD INSTRUMENTS LIMITED, Stratford, Ontario, Canada
Telephones: 3717 & 3718

MUIRHEAD & CO. LIMITED, Beckenham, Kent, England
Telephone: Beckenham 4888

439

CIRCLE NO. 24 ON INQUIRY CARD

DIGITAL MAGNETIC MEMORY DRUM

True Flux Responsive Readout is Independent of Drum Speed

Unlike conventional high-density, computer drums in which relative motion between the read head and the "spot" magnetized recording is necessary to induce millivolt output, the read heads of a magnetic memory drum, called Dynastat, respond solely to the polarity of the recorded magnetic field to yield an output of sufficient power which is directly applicable for logic action.

The read heads are self contained bi-stable magnetic amplifiers which are triggered by an external magnetic field of a particular polarity. In recording or writing, the magnetic material on the drum is magnetized with one polarity for "zero" or "off" information and with the opposite polarity for "one" or "on" signals. When the read head encounters a "zero" polarity record, the output remains at minimum noise level; when a "one" polarity spot is presented, the output snaps to full voltage. The true flux responsive readout, being independent of drum speed, is the same at standstill as at high rotational velocities.

Two types of direct output from the read heads are available. For operation into transistor circuitry, the output is rectified and matched for low impedance; "one" output is 1.5 volts dc into 1,000 ohms and "zero" output is less than 30 millivolts. For operation into a cold cathode matrix, the "one" output is 65 volts ac; "zero" output is less than two volts.

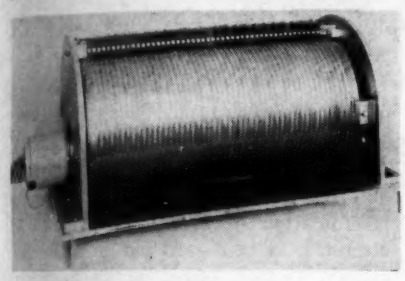
Developed by Consolidated Controls Corp., Bethel, Conn., the drum performs such functions as variable delay for the master control of automatic inspection devices, conveyors and materials handling equipment, program control for automatic machine tools and other equipment and synchronous conversion of binary codes from parallel to serial and reverse.

Among the advantages which Consolidated Controls Corp claims for its Dynastat drums are: non-destructive recovery of stored information which eliminates the necessity for external recirculating delay lines and registers; rugged construction and uncritical tolerances; and the absence of moving parts which together with bistable readout heads assures positive recovery of stored program.

Drums may consist of single information channel or as many parallel channels as required to handle binary cod

words of any size. Many types of drum drives are available. For some applications direct power take-off to maintain synchronism with the process being controlled is used; for others, a remote servo repeater is recommended, often including a selsyn follow-up system. For stepping applications, electromagnetic stepping drives are supplied.

An integral part of each drum is the power supply which produces the



Multiple unit Dynastat drum with 15,000 bit binary storage.

proper parameters for driving the write heads and for exciting the read heads. Solid state circuitry converts available signals to the proper power levels for writing and adapts standard drum output signals for direct application to motors and actuators.

Write No. 153 in Box on Inquiry Card

WORTH FILING

RF Connectors

32 page rf connector catalog provides complete information on both standard and special types, including various configurations of captive pin cable plugs/jacks, waveguide adapters and complete listings of caps, receptacles, etc. Outstanding features of TNC series types are low VSWR, reduced noise level and minimum insertion losses.

For your copy write on company letterhead to;
General RF Fittings, Inc.
702 Beacon St.
Boston 15, Mass.

Industrial Engineering Conference

The annual regional conference of the American Institute of Industrial Engineers will be held in Boston, Mass. on November 3 and 4, 1960. Some of the topics of discussion include: computer applications in manufacturing; value engineering and analysis; simulation, models, and mathematical programming.

For More Detailed Information Write No. 178 in Box on Inquiry Card

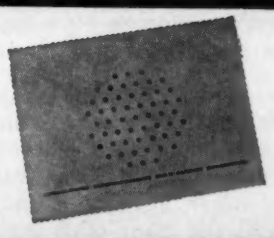
CIRCLE NO. 25 ON INQUIRY CARD→

PUT YOUR CONNECTOR NEEDS IN CAPABLE HANDS

What type of connector for you? CEC can meet virtually any application need with its line of standard connectors and its capability in the design of special types.

Look at the variety of CEC's standard connectors: rectangular types with snap-in, crimp-type contacts in 14- to 104-contact configurations... rack and panel types with high-strength, die-cast polarizing shell containing both standard and coaxial contacts... circular MS types (MIL-C-26500) with immersion-resistant characteristics in 15- to 55-contact configurations for use in critical environments... and circular types for non-critical industrial applications.

Regardless of the application, you can depend on CEC know-how and experience to meet your connector requirements. From CEC's extensive engineering and manufacturing facilities comes a complete line of connectors with a full guarantee of reliability.



Write for the new brochure "Consolidated Electrodynamics Multi-Contact Connectors." It describes CEC's modern connector manufacturing facilities. Ask for CEC Bulletin 4004-X29.

Electro Mechanical Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell · *FINER PRODUCTS THROUGH IMAGINATION*

why

PERMANENT MAGNETS ARE PERMANENT!

TRULY PERMANENT permanent magnets are now possible, according to scientists of Indiana Steel Products Division, Indiana General Corporation. The following conclusions were gained during a special research project conducted by Indiana and supported by funds of the United States Air Force.*

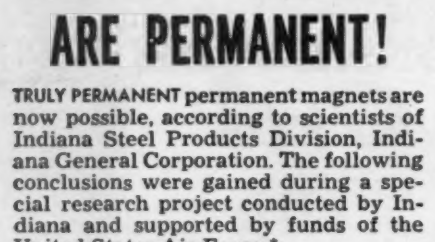
NATURAL STABILITY

1. Materials having the highest coercive force displayed the greatest natural stability.

2. Rods of ALNICO V having a greater length-to-diameter ratio proved more stable.

3. Where change in remanence was perceptible, it was found that it decreases linearly with the logarithm of time. (See Fig. 1.)

Fig. 1. Remanence decreases with time.



TEST CONDITIONS

Sample magnets under study were kept in a special room where they were relatively free from external demagnetizing influences. Temperature was kept virtually constant at 24° +2.5°C. The sensitive measuring apparatus, also located in the test room, permitted measurements to an over-all tolerance of better than 1 in 10,000.

ARTIFICIAL STABILIZATION

Two methods of achieving complete stabilization — often required in critical applications — were proved successful. Both involved artificial reduction of remanence.

Temperature Knockdown—several cycles of low temperature exposure, to −65°C, produced the greatest stability.

Knockdown by Applied AC Field—magnets were subjected to a cycling diminishing field. Stability was best achieved when remanence was reduced to between 5 and 15%.

This study indicates that permanent magnets *can* be completely stabilized. A magnet, however, that is perfectly stable under test conditions can still be affected by temperature variations, vibrations, stray magnetic fields and many other factors. In the case of selected magnets, stability *can* be guaranteed for a flux change no greater than 0.01% per year.

For complete information on the practical aspects of "stability," and for a summary of experimental results, ask for a copy of Applied Magnetics, First Quarter, 1959. Write Dept. V10.

*Contract AF33 (616) — 3385 monitored by the Aero. Res. Lab., WADC.

DIVISION OF INDIANA GENERAL CORPORATION

INDIANA STEEL PRODUCTS
VALPARAISO, INDIANA
In Canada: The Indiana Steel Products Co. of Canada Limited, Kitchener, Ontario

INDIANA PERMANENT MAGNETS

CIRCLE NO. 26 ON INQUIRY CARD

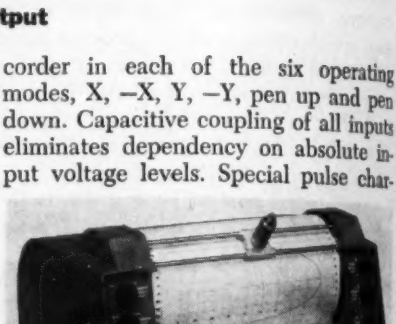
DIGITAL INCREMENTAL RECORDER

Unit Plots Directly from Computer Output

High speed, precision plotting of computer processed data is made possible with an X-Y recorder developed by California Computer Products, Inc., Downey, Calif. The recorder converts digital informaton regarding the relative variation of two functions into corresponding incremental motions of the plotting paper and the plotting pen. Accuracy is within one-hundredth of an in. which is the size of the basic ploting increment.

Incremental movements of the recording paper drum provide one axis motion and the incremental movements of the ball point recording pen provide the second axis. Z-axis modulation is accomplished by raising and lowering the recording pen with a solenoid to control contact with the paper. The model 560-RX-Y plotter provides up to 200 incremental steps per sec. on each axis and Z-axis modulation can be maintained at up to ten operations per sec.

Bi-directional rotary step motors drive the paper drum and the recording pen carriage. The damping applied to the drive mechanism makes it possible to use the full high speed capabilities of the step motors. Twelve electrical inputs are provided so that either positive or negative polarity signals can be used to drive the recorder in each of the six operating modes, X, −X, Y, −Y, pen up and pen down. Capacitive coupling of all inputs eliminates dependency on absolute input voltage levels. Special pulse char-



acteristics can be accepted by simple modification of the input circuits. All circuitry is mounted on a removable etched circuit board or in a plug-in power supply module.

The unit can accept data from all digital computers and can be driven by both punched paper tape and punched card data processors. These capabilities give the plotter excellent on-line and off-line potential in such applications as monitoring industrial processes, evaluation of pjrocessed test flight data, statistical surveys and analysis of time varying systems by digital differential analyzers. The incremental design is said to eliminate problems of drift, stability and gain variation.

Write No. 159 in Box on Inquiry Card

WORTH FILING

Controllable Inductors

"Designing for Stability," a two part technical article, discusses the use of electrically controllable inductors in applications where effects of temperature change and hysteresis must be minimized. Part I describes the effects of hysteresis and temperature changes and various open loop methods for minimizing these effects. Principles and general considerations of closed loop, bellweather stabilization are also discussed. Part 2 deals with specific closed loop and bellweather stabilization circuits.

Source: Trak Electronics Company
Wilton, Conn.

For your copy: Write No. 816 in Box on Inquiry Card

Allied Radio Corp's 561 page 1961 catalog of electronic equipment lists over 48,000 items, including semiconductors and diodes, transistors, panel meters, nuvistors, termisters, standard and special purpose electronic tubes, miniature industrial fans, ultrasonic cleaning equipment, test instruments, voltage stabilizers, transformers, attenuators and controls, resistors, capacitors, printed circuit components and many other items.

Source: Allied Radio Corporation
Chicago, Ill.

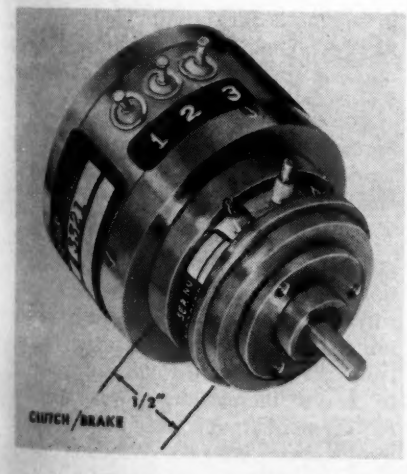
For Your Copy: Write No. 817 in Box on Inquiry Card

CLUTCH/BRAKE POT MODULE

Coupling and Alignment Errors Eliminated

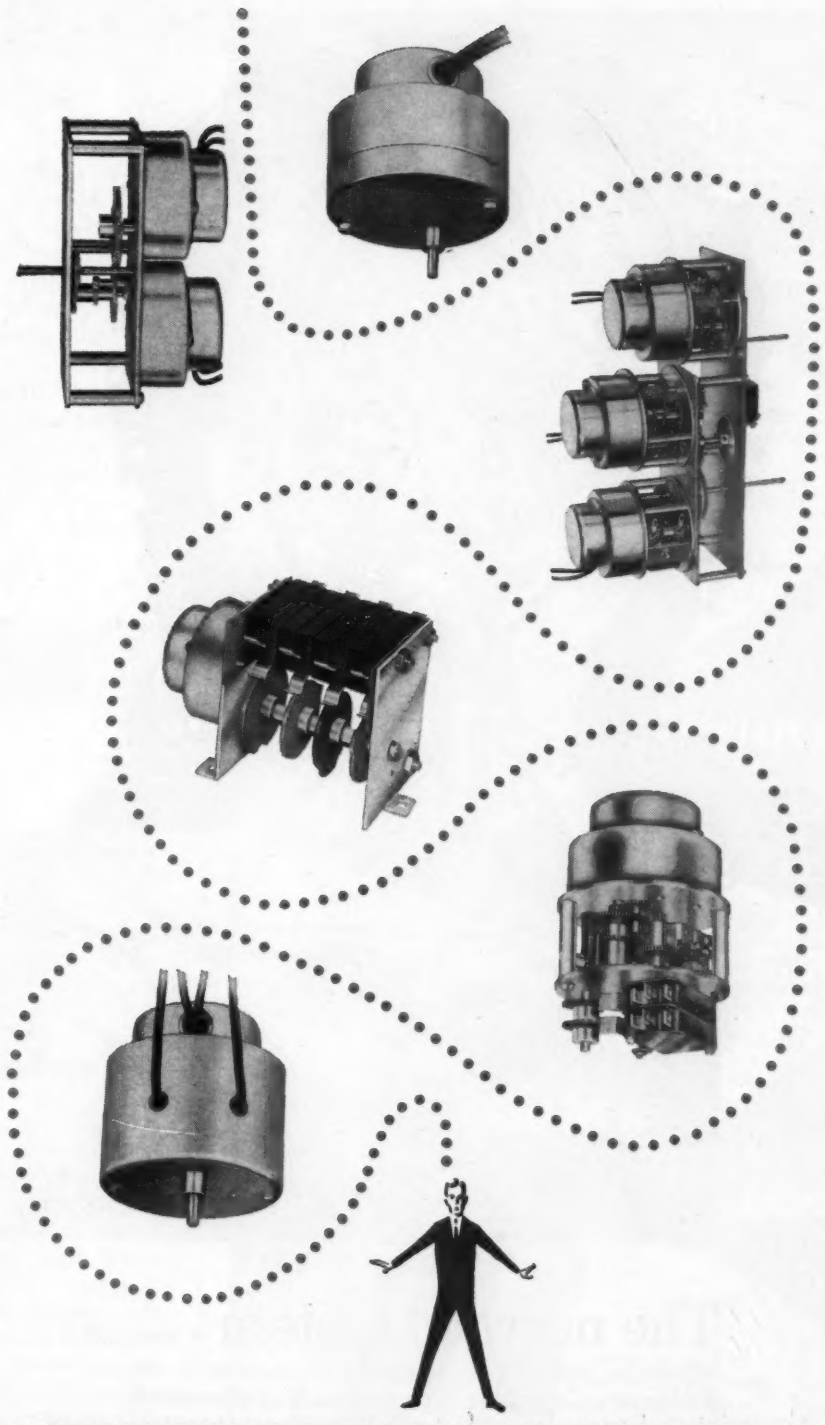
The requirement for a shorter unit capable of delivering almost the same performance as previous precision clutch/brake combinations resulted in the development of a clutch/brake potentiometer module consisting of a clutch/brake unit with a special end cap that is also the potentiometer mounting plate and part of the housing. Designed by Autotronics, Inc., Florissant, Mo., the complete assembly is a single, permanently sealed unit with a common shaft and integral bearings. Since this clutch-pot is a single unit, the problems of coupling backlash, shaft mis-alignment, end play and excessive bearing drag are eliminated.

Output shaft of the "pancake" clutch/brake unit is the rotating shaft of the potentiometer upon which is assembled the wiper arm of the pot. Since this shaft is one single piece, there is no problem of coupling error or alignment error. The bearing bore and the winding cup mounting recess are machined to extremely close tolerances so that there is no chance of eccentricity. The elimination of the coupling has also allowed the use of smaller masses in the unit which in turn make the entire assembly less susceptible to the forces of high G loads.



Reduction of the mass of the movable elements allows the designer to place these units in the planes that are most advantageous to the reliable operation of the potentiometer and disregard the possible effect of G loading on the clutch itself. Extensive evaluation has shown that shock and acceleration forces in excess of 100 G have no effect on performance. Reduced physical size of the clutch-pot unit allows the design of a much more compact system.

Write No. 152 in Box on Inquiry Card



IS FINDING THE RIGHT TIMING DEVICE YOUR PROBLEM?

Call in the Man from Bristol Motors! He talks your language—knows how to meet your needs and problems. Whether you require a standard motor, a modification of a standard, or a new design, Bristol experience can be counted on to give you quick delivery of the timer best suited to your needs. A wide torque range is available—speed ranges from 1800 rpm to 1 rp month! You can get variations in shaft length, voltages, shift and brake action and other special features for your specific needs. For dependable, economical synchronous timing in industrial control and instrumentation—ask for the Bristol Motors Representative in your area.

Write for new Catalog 160.

BRISTOL MOTORS

Division of Vocaline Company of America, Inc.
210 Coulter Street, Old Saybrook, Conn.

Dept. ED-10 VB-2

CIRCLE NO. 27 ON INQUIRY CARD

The nervous system of this ASR-3

submarine detecting set gets surgical attention at Singer-Bridgeport. Capability in electro-mechanical assembly and precision machining is now being demonstrated in a range of military and industrial projects at this fast growing facility.

To meet critical prime and subcontract production requirements, Singer-Bridgeport offers both engineering capability and unexcelled facilities. Test and quality control equipment encompass environmental, acceleration, vibration, shock temperature, altitude, humidity and salt spray in simulation of extreme adverse operating conditions.

These extensive facilities for engineering, test and production are described in a comprehensive brochure. It is yours for the asking.

8999

SINGER*

SINGER-BRIDGEPORT

A DIVISION OF THE SINGER MANUFACTURING COMPANY

915 Pembroke Street Bridgeport 8, Conn.

*A Trademark of THE SINGER MANUFACTURING COMPANY

CIRCLE NO. 28 ON INQUIRY CARD

WORTH FILING

Switches

Five basic catalogs cover hermetically-sealed and environment free switches; 30 basic styles of indicator lights; basic precision switches; control switches; and electroluminescence paneling, an innovation in "cold light." Engineering data and specs given for all components.

Source: Controls Company of America
Folcroft, Pa.

For Your Copy Write No. 812 on Inquiry Card

R. F. Shielded Chambers

Twenty-four page brochure on R.F. shielded chambers describes the complete service from engineering design through erection and testing. It also depicts many of the components making up a shielded chamber.

Source: Emerson & Cuming, Inc.
Canton, Mass.

For Your Copy Write No. 814 on Inquiry Card

Magnetic Pickups

Booklet explains how transducers, which generate voltage and power without the aid of power supplies, can be used for extremely accurate mechanical-electrical conversion. Selection guide chart describes the devices in terms of physical size, electrical output, temperature range and types of mating connectors required. Typical curves show voltage output and power output. Block diagrams illustrate use of magnetic pickups for counting revs, as a tachometer, for measuring speed and for reversing direction of motion.

Source: Electro Products Laboratories
Chicago, Ill.

For Your Copy Write No. 813 on Inquiry Card

Microwave Pressure Windows

Twelve-page brochure describes waveguide pressure windows, their application and installation suggestions. Pressure windows are available as standard units to operate in frequency range from 2.4 to 40 kMc and are designed to serve increasing power handling requirements over exceptionally wide temperature ranges. Windows freely propagate RF energy over a specific bandwidth of frequencies and seal off sections of waveguide in radar or other microwave waveguide applications where pressure, humidity, and dust seals are required. Window types covered are flange-mounted glass-kovar; flange-mounted mica; pressure window-waveguide assemblies; and solderable windows (including new flex-frame construction) for sealing reference cavities, filters, etc.

Source: Microwave Associates, Inc.
Burlington, Mass.

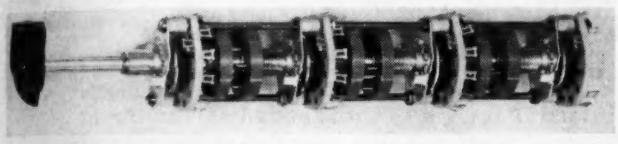
For Your Copy Write No. 811 on Inquiry Card

N-DIGIT DECADE SWITCH

"Combination-Lock" Memory Switch Stores Multiple-Digit Numbers

Most memory switches store only one digit. Thus to store numbers containing several digits has required a switch for each digit with a separate dial for each switch. Using principles of the ordinary combination lock, Paul D. Shannon of the Massachusetts Institute of Technology Instrumentation Laboratory has developed a memory switch capable of storing multiple-digit numbers in a single unit.

So close does the switch follow combination lock principles that Shannon obtained parts for his first prototype by stripping discarded laboratory locks. In operation the switch is first "cleared" and then digits are set into it by turning the shaft alternately to the right and left, one less revolution each time, after the fashion of a combination lock.



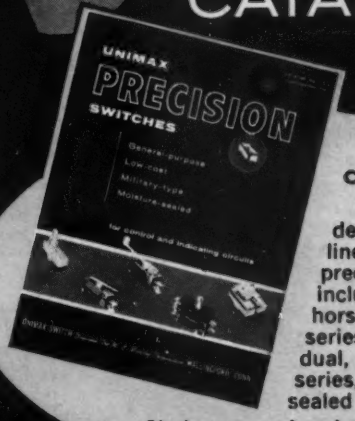
The n-digit switch consists of sets of switch indexes and wafers coaxially arranged with tumbler-type couplings between. The number of indexes depends on the number of digits to be stored. The prototype stores four-digit numbers and, therefore, uses four switch indexes and wafers. Number of positions on each index wafer depends on the function for which the switch is designed. Twelve-position indexes were used in the prototype so that each digit could be 0 to 9 or plus or minus. Each index, except for the outermost is associated in operation with a drive tumbler-fly tumbler set like those of standard combination locks.

In operation of the switch, as the shaft turns continuously in one direction, the first drive tumbler rotates until its drive pin engages the first fly. The fly rotates at most about 60 degrees then engages the fly pin portion of the fly tumbler. The first fly tumbler rotates the shaft, turning the second drive tumbler until its drive pin engages the second fly, fly pin and fly tumbler. In this manner, after three revolutions at the most, rotary motion is transmitted to the fourth index and it can be set in the desired position. The other three indexes are set—as in the combination lock—by turning the input shaft alternately one way and then the other, one less revolution each time. The outermost index is set lastly, and directly, by final rotation of the shaft.

After the n-digit switch has been assembled, it must be adjusted for the proper sequence of operation. First, the positions of the shaft are given values—0 to 9 or plus or minus in the case of the 12-position index. Next, drive tumbler set screws are loosened and all drive pins aligned in approximately a straight line with each wafer set in the same position.

The set screws are tightened and the fly tumblers rotated until each fly is snug between a drive pin and a fly pin in such a way that all four shafts can be rotated in one direction with each index progressing properly through its detents. When all detents are working properly, the set screws are tightened. All six tumblers—in the case of the four-digit prototype—are then drilled, reamed and pinned to their respective shafts with taper pins. • • •

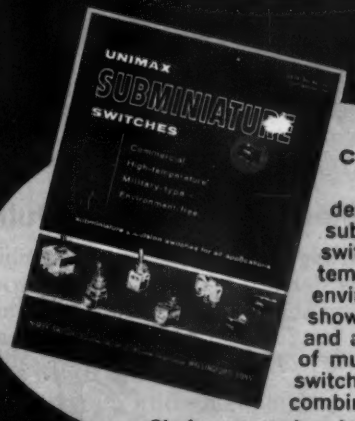
3 NEW UNIMAX SWITCH CATALOGS



PRECISION

CATALOG 10-1
describes complete line of phenolic-cased precision switches, including the new, horsepower-rated 2HL series, the new, dual, low-cost DA series, and three new sealed series.

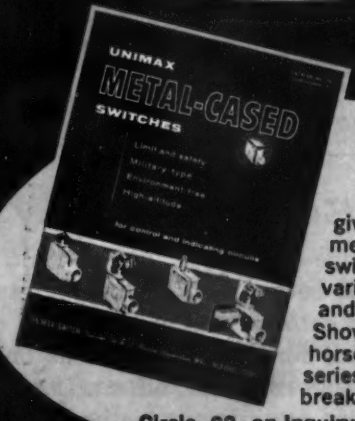
Circle 60 on Inquiry Card



SUBMINIATURE

CATALOG 20-1
describes subminiature switches, including high-temperature, sealed, and environment-free styles; shows 5 terminal styles, and a wide variety of multiple-switch/actuator combinations.

Circle 61 on Inquiry Card



METAL-CASED

CATALOG 30-1
gives details of metal-cased limit switches, with a variety of actuators and housings. Shows new, horsepower-rated KL series and double-break BK switch.

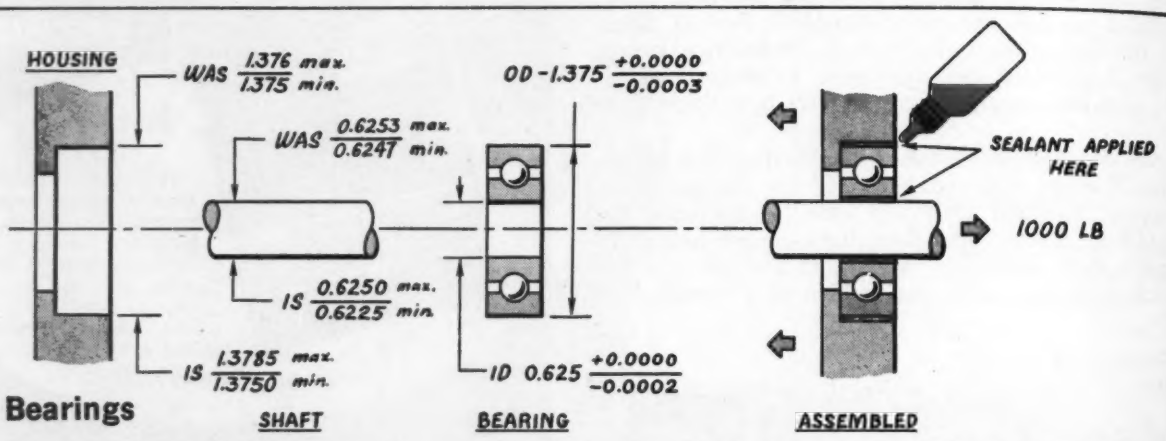
Circle 62 on Inquiry Card

Each catalog includes a useful section telling how to choose the proper switch for the service required; also photographs, dimensioned drawings and force and movement specifications for all switches. *Ask us for the catalog you need; it's free on request to*

UNIMAX SWITCH
Division, The W. L. Maxson Corporation
IVES ROAD, WALLINGFORD, CONNECTICUT

SIMPLIFY ASSEMBLY...
Retain parts on shafts with slip fit and Loctite

Designing with liquid LOCTITE eliminates press fits, shrink fits, broaching, knurling, keyways, set screws and pinning ... provides easier tolerances ... cuts rejects and rework.

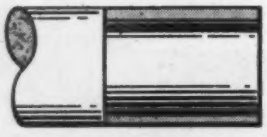


Bearings

LOCTITE Sealant replaced press fit, opening up tolerances .002 inch on shaft and housing. Rejects were cut from 8% to 1% and rework from 20% to 0! Bond to inner race withstands 1000 lbs. thrust ... equal to the best press fit. Slip fit with LOCTITE gives more uniform retention ... eliminates fretting damage due to loose "press fit" or bearing distortion resulting from tight press fit ... assures better shaft alignment. Easier tolerances speed assembly.

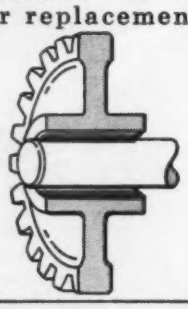
Hardened Sleeves

Eliminates shrink fit ... mounts hardened sleeve without pulling temper.



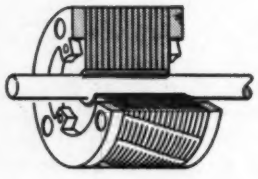
Gears and Pulleys

Eliminates broaching, knurling, shaft distortion. Easier gear replacement.



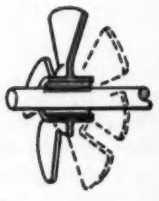
Rotors

Eliminates shaft distortion and resulting regrinding & straightening.



Fans

Eliminates set screws ... no amount of vibration will loosen part.



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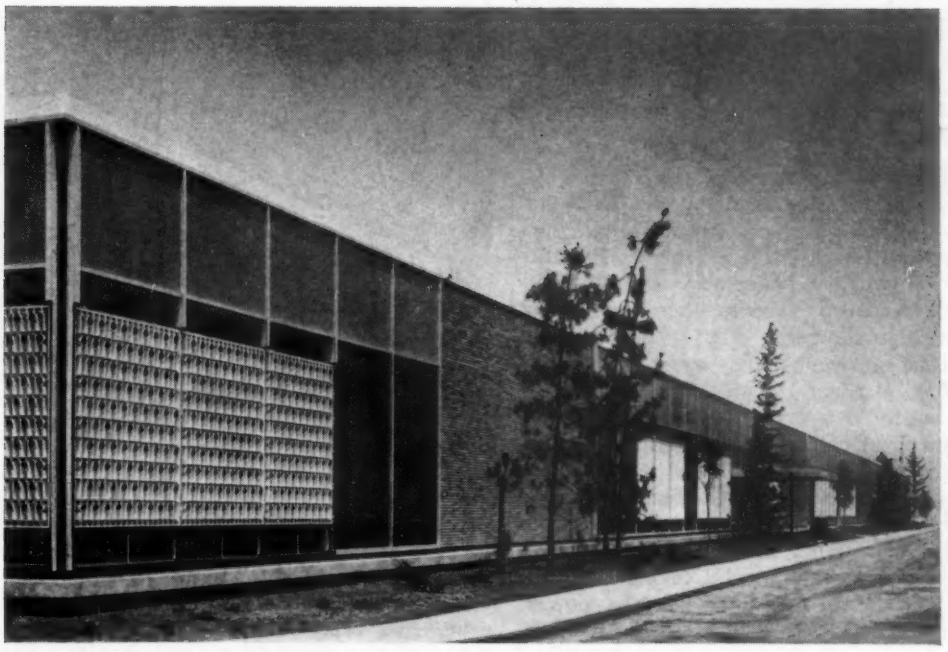

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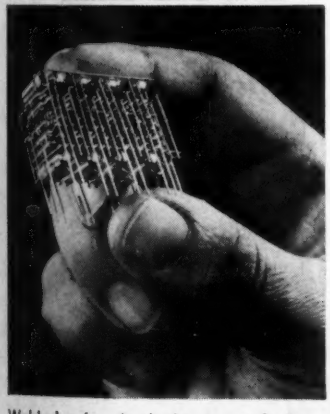
Merritt MacKnight, Manager, Systems Development Department, demonstrates the sophisticated design of a Litton digital computer assembly for the new Grumman A2F.



Welded wire techniques substantially increase component packing densities.

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HEAT-ELECTRICAL ENERGY CONVERSION

THERMIONIC CONVERTERS

Three Oz. Static Power Generator Produces a Minimum of One Watt

Practical, commercially available sealed-off thermionic converters are now being turned out in production quantities by the General Electric Company, Schenectady, N. Y. The close-spaced vacuum thermionic converter, shown in Fig 1, produces at least one watt and is about the size of half a silver dollar. Minimum power density is 0.2 watts per square centimeter of cathode surface and minimum thermal efficiency is 2.5%, operating at a cathode temperature of approximately 1100 C. Efficiency, power output and life expectancy are expected to be improved; developmental vacuum devices have been operated with a power density of one watt per square centimeter and with an efficiency higher than 4.5%.

In the field of vapor thermionic conversion, General Electric's research scientists have operated laboratory models, using cesium vapor, which produce 7.5 watts per square centimeter at 15% efficiency. One of the lab models is shown in Fig 2. Outputs as high as 20 watts per square centimeter and thermal efficiencies as high as 30% (approaching that of a steam turbine) are believed attainable with vapor thermionic converters.

Dr. A. O. Jensen, Research Engineer in G.E.'s Power Tube Department, discussed briefly the general operating characteristics of thermionic converters.

Dr. Jensen viewed the thermionic converter as a static heat engine where the electrons serve as a working fluid. The main problem, he stated, is to force the electron working fluid to circulate in the heat engine system with a minimum expenditure of energy.

Fig 1 G. E.'s commercially available Vacuum Thermionic Converter. Present production capability is 60 converters per week but can be increased to 100 per week according to the company. The unit has a practical and reliable high temperature envelope for operation in an oxidizing atmosphere.

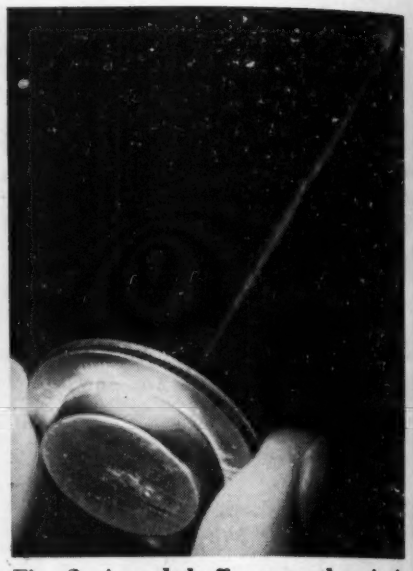

Fig 2 A sealed-off, vapor thermionic converter which General Electric plans to make in production quantities. Stem-like extension from anode side is cesium reservoir.

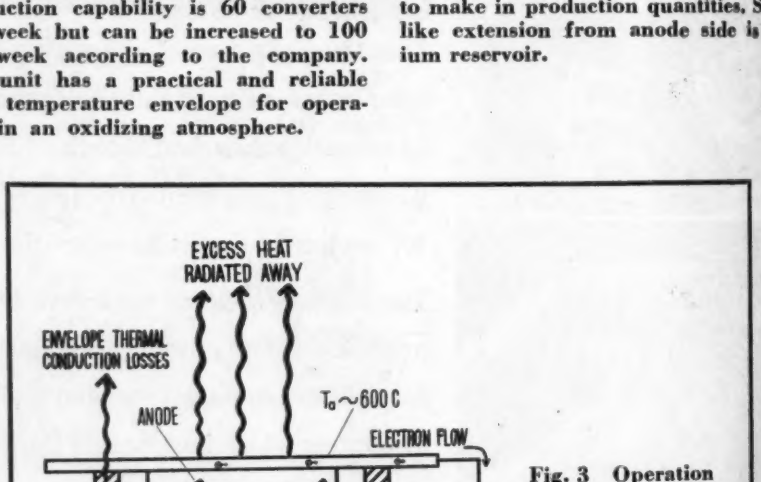

Fig. 3 Operation of the vacuum thermionic converter.

VACUUM THERMIONIC CONVERTER

Fig 3 illustrates general operation of the vacuum thermionic converter. Heat energy supplied to the cathode region of the device energizes the free electrons existing in the cathode material. When enough heat energy is supplied, these free electrons become so energetic that they boil out of the cathode surface and into the region between the cathode and the anode. At this point each electron has been lifted over the cathode surface energy barrier (specifically called the cathode work function) and possesses a potential energy equal to the surface barrier height, as shown in Fig 4. The great majority of these emitted electrons have expended most of their kinetic energy in overcoming the barrier and drift rather randomly around, just outside the cathode surfaces. Unless these random electrons can be rapidly removed from the region just outside the cathode, this cloud of electrons, termed space charge, tends to inhibit the release of subsequent electrons from the

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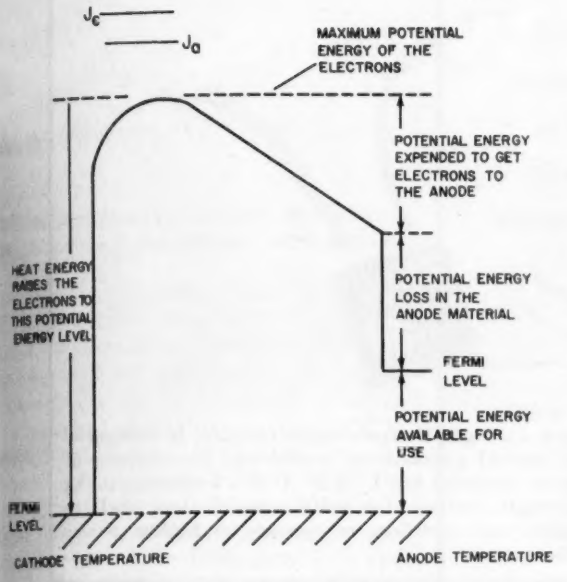
J_c
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MAXIMUM POTENTIAL ENERGY OF THE ELECTRONS
POTENTIAL ENERGY EXPENDED TO GET ELECTRONS TO THE ANODE
HEAT ENERGY RAISES THE ELECTRONS TO THIS POTENTIAL ENERGY LEVEL
POTENTIAL ENERGY LOSS IN THE ANODE MATERIAL
FERMI LEVEL
POTENTIAL ENERGY AVAILABLE FOR USE
FERMI LEVEL
CATHODE TEMPERATURE
ANODE TEMPERATURE

Fig 4 Thermionic converter potential energy.

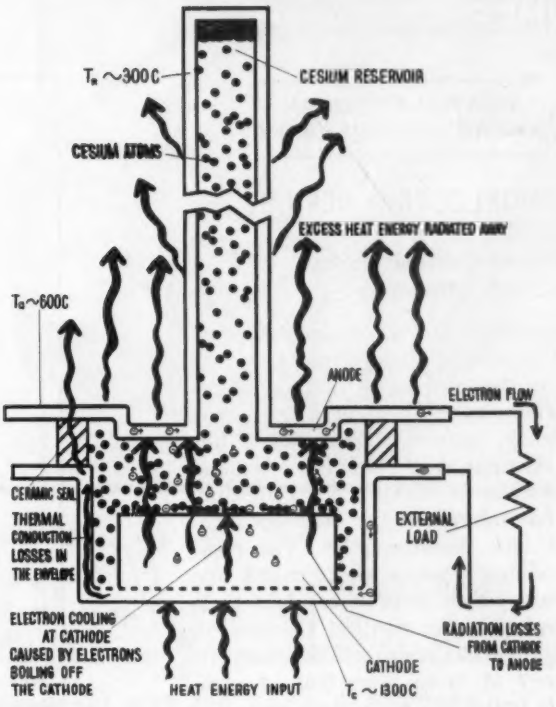

Fig 5 Operation of the vapor thermionic converter.

cathode. It is this buildup of space charge which constitutes one of the major problems in thermionic converters.

To get these electrons out of the region in front of the cathode and over to the anode, the effect of space charge is minimized by physically locating the anode extremely close to the cathode. The spacing in G.E.'s production unit is of the order of 0.5 mil.

The electrons so far have been elevated to a height (potential energy) represented by the cathode surface energy barrier. This potential energy is now available for use at the anode. These electrons now have to find their way into the anode material, and, in the process of thermalizing with the anode electrons already there, they lose some of their potential energy. To minimize this loss, the anode work function has to be small as possible. The electrons still have enough potential energy, however, so that if an external path is provided, they will seek to return the cathode and do useful work in an external load. This constitutes the useful electrical output of the converter. It represents what is left of the initial heat energy supplied to energize the electrons in the cathode.

If the anode material becomes too hot, the electrons will become just as energized as those in the cathode. They would then attempt to boil back out of the anode. This effect in a thermionic converter is called back-emission, and its occurrence reduces the net flow of electrons across the tube from cathode to anode. Since reduction in the net electron flow from cathode to anode obviously diminishes the power output of the device, the anode must be maintained at a lower temperature than the cathode. Radiation cooling is an accepted method of doing this.

The efficiency of this process of cycling an electron working fluid is governed by several additional factors. Not all the heat energy applied to the device is used in lifting the electrons over the cathode surface energy barrier. Some of this heat energy passes directly through the cathode to anode space and is termed radiation energy loss. The amount of this loss is dependent on the surface characteristics of the anode and the cathode.

Another part of the incident heat energy is conducted away from the cathode through the walls of the device and through the spacers between the cathode and the anode. These losses are generally termed the thermal conduction loss and represent one of the major factors which differentiates a practical sealed-off production thermionic converter from most laboratory models. To achieve practical efficiency from a production converter, major efforts in materials technology and design have been and will continue to be required to minimize this thermal conduction loss.

VAPOR THERMIONIC CONVERTER

In a vapor thermionic converter, illustrated in Fig 5, a more subtle method of reducing space charge effects is employed. An agent in the form of ions is introduced into the space charge region to nullify the effect of the space charge. This is termed space charge neutralization, a basic principle of the vapor thermionic converter. The particular neutralizing agent used in G.E.'s laboratory models is the cesium ion which requires a cesium reservoir.

Another important difference between the vacuum and the vapor converter is that in the vapor converter the neutralizing agent may also aid the emission of the electrons from the cathode. In fact, the cathode can be simply a bare refractory metal such as molybdenum with a partial covering of cesium. This has the great advantage of increasing cathode life by continuous regeneration of the emitting surface.

Much higher cathode emission densities with long life can be achieved in the vapor converter, leading to much higher power output for the same size device. Generally, the descriptions of thermal losses pertaining to the vacuum converter also pertain to the vapor converter.

Although only two methods of reducing space charge effects in thermionic converters were discussed, there are other possible approaches. For example, external electric and magnetic fields can be applied to a vacuum converter in such a manner that the electrons are moved out of the cathode region before they are able to influence the electrons behind them.

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HEAT-ELECTRICAL ENERGY CONVERSION

THERMOELECTRIC DEVICES

Heating or Cooling Module Rates High Efficiency

Development of a semiconductor alloy, called Neelium, has given new impetus to the application of thermoelectric principles. The material, a quaternary alloy, consists of bismuth, tellurium, selenium and antimony. General Thermoelectric Corp. of Princeton, N.J., has fabricated the Neelium compound into thermocouples. The company claims that a unit, called the Frigistor, which consists of eight thermocouples, is the smallest thermoelectric module available and they rate its efficiency at more than that of comparable units.

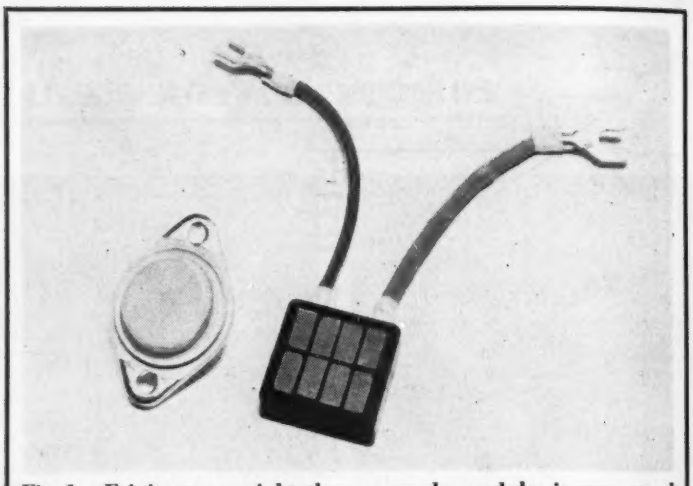

Fig 1 Frigistor, an eight thermocouple module, is compared in size with a typical germanium transistor. Dimensions of the thermoelectric modules are 1″ X 1″ X ¼″. Frigistors make it possible, through cooling, for solid state devices such as transistors, diodes and rectifiers to operate at higher power and greater efficiencies.

FRIGISTOR

The Frigistor assembly is completely sealed in a high impact strength plastic case. The only metallic parts exposed are the copper connector bars which serve as the heat transmission elements. All surfaces are ground and lapped for maximum heat transfer. Frigistors are mounted by means of a special Neelium adhesive which insures maximum heat flow through the module from absorber to radiator.

Typical applications for Frigistors include their use in devices which pump heat away from high power transistors to a heat sink. Heat pumping capacity of a Frigistor is as high as 10 to 15 watts. Units are available which use currents as low as 5 amperes at ½ volt. Frigistors that cool high frequency germanium transistors with flat L, U or square shape cold junctions permit operations at temperatures up to 150 C. Silicon power transistors, cooled with Frigistors will operate at temperatures over 300 C.

THERMOELECTRIC EXPERIMENTAL KIT

General Thermoelectric Corp. has also developed an experimental kit designed for the study of basic thermoelectric principles. The kit contains all of the necessary tools for thermoelectric cooling experimentation, including: a Frigistor module; two fin assemblies, one for use at the hot junction for heat dissipation, the other for mounting transistors which require cooling; a single Neelium thermocouple; a special heat-conductive adhesive; a special insulating material; an appropriate power supply; and a booklet for use as a guide in calculating hot and cold junction temperatures and heat pumping capacities.

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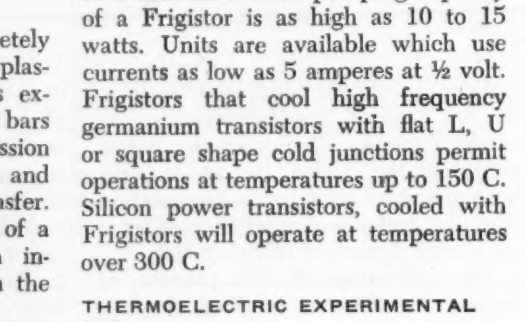

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Fig 2 Simplified cooling of electronic devices is one of the principal applications of Neelium. The constant temperature container, illustrated above, is capab'e of maintaining a 40 C temperature to 0.1 C accuracy over an ambient range of −50 to +70 C.

NEW THERMOELECTRIC ALLOY

Silver Antimony Telluride Shows High-Energy Conversion Efficiency

Studies are underway at Bell Telephone Laboratories on one of the most efficient thermoelectric materials yet developed. The compound, first discovered by J. H. Wernick of Bell Telephone Laboratories, is composed of silver, antimony, and tellurium. Its chemical designation is silver antimony telluride ($AgSbTe_2$). Many compounds and alloys, some with as many as seven elements, have been produced and studied, but according to Bell scientists the best of these discovered to date has been the silver antimony telluride.

Synthesis of these alloys by Dr. Wernick involves the direct fusion of stoichiometric quantities of the desired elements. Zone refining is then used to produce pure samples. The material possesses a very low thermal conductivity which is necessary in order to maintain a temperature differential between two ends of a device. Its thermoelectric figure of merit, "Z", has recently been measured by scientists at RCA and is reported to be about 1.75 x 10^{-3}/C over a range of 200 to 500 C, which is the best yet observed for p-type thermoelements in this range.

Silver antimony telluride was described as having a disordered cubic structure, exhibiting a thermal conductivity as low as 0.0064 watts/cm C at room temperature, only one one-hundredth that of germanium. While the material is always thermoelectrically p-type, its Hall effect is p-type in some specimens and n-type in others, even when taken from a single ingot. Dr. R. Wolfe, Dr. J. H. Wernick and S. E. Haszko, all of Bell Laboratories, attributed this anomolous behavior to the presence of a small amount of a second phase consisting of silver telluride, which is swept to one end by zone refining. This n-type compound appears to dominate the room temperature Hall coefficient at concentrations as low as 10 to 20%, while the p-type silver antimony telluride dominates the thermoelectric properties. Further studies of these anomalies are in progress and are expected to advance considerably the knowledge of semiconductors in general.

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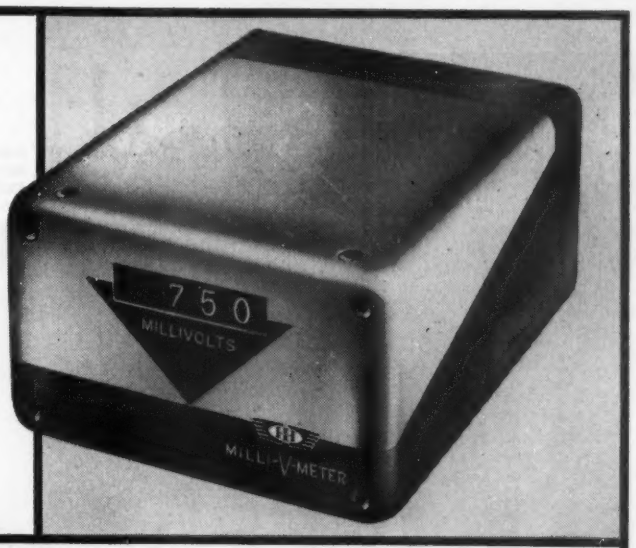

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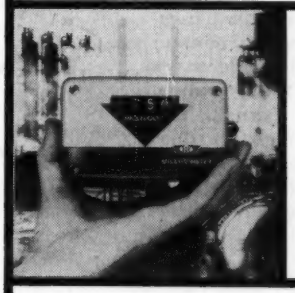

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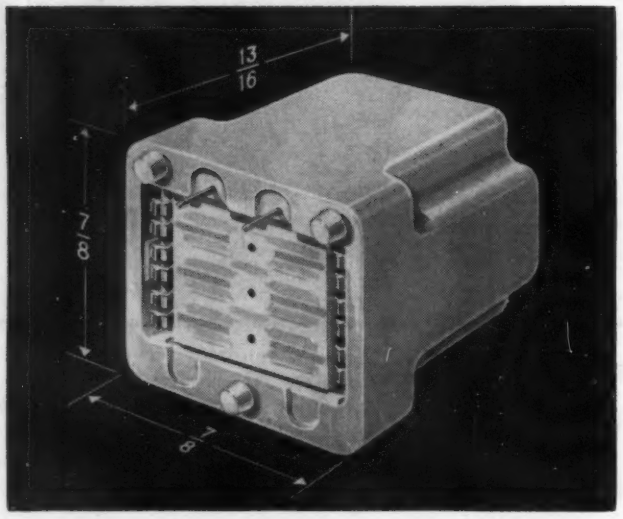
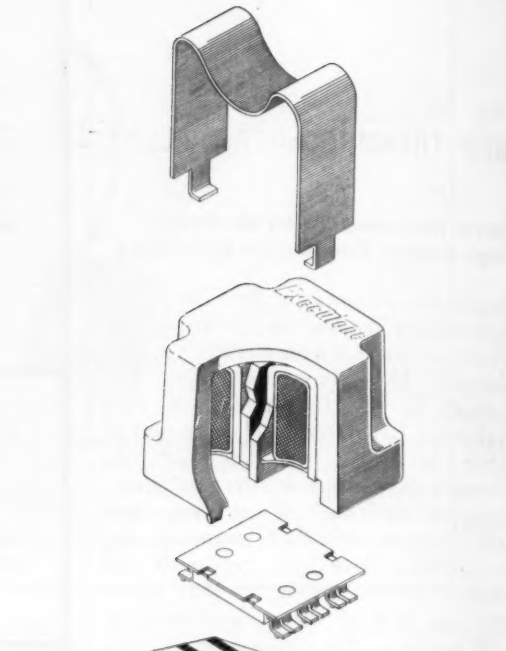


Printact, the permanent magnet relay developed by Executone, Inc., is molded in high-impact plastic for direct mounting on printed circuit boards. The relay's principal advantage, in addition to cost, space and weight savings, is reliability. The pre-adjusted, prestressed contact springs assure constant pressure. All of the tolerances are designed into the precision tooling for the armature assembly and the micro-processed contact springs. The solid molded magnetic motor assembly serves as a dust cover for the entire contact system. If desired, further protection may be achieved by applying a fillet of epoxy cement around the relay after it is mounted on the printed wiring board.



The Printact relay is accurately positioned on printed circuit board by guide pins and holes in the board. A simple spring clamp holds the relay in position. The moving contacts on the relay armature assembly mate directly with conductors on the printed circuit board. The conductor pattern is designed by the user to meet specific application problems.

PERMANENT MAGNET RELAY

Constant Force on Armature Eliminates Need for Adjustment

Principal problems that plague equipment using relays include difficulties in maintaining proper spring tension after repeated operations, foreign matter getting between the contacts, corrosion, etc. Representing a new approach to relay design, Printact, a printed contact, permanent magnet relay overcomes these problems to a great degree.

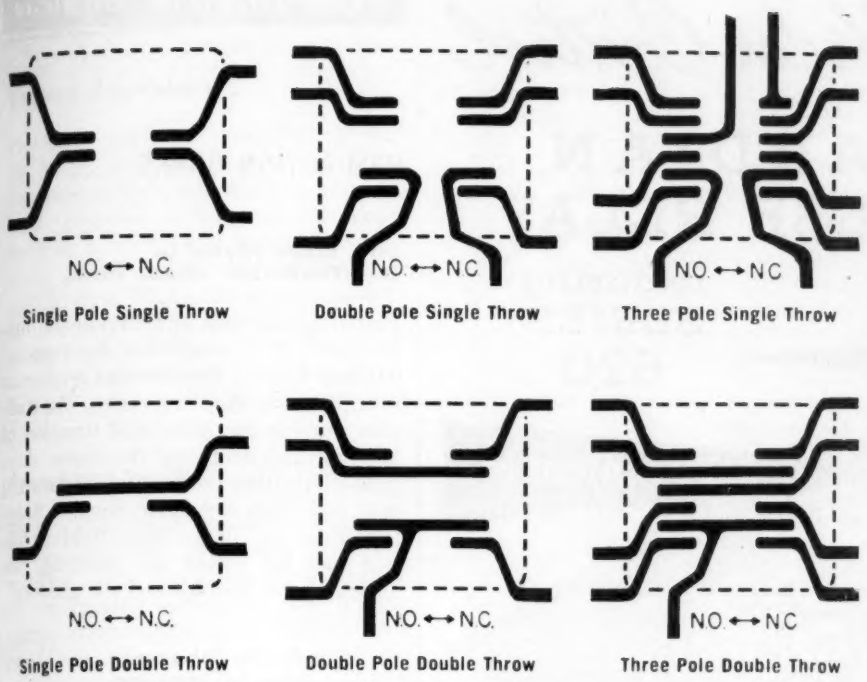
Developed by the Components Div., of Executone, Inc., Long Island City, N.Y., the unit performs the same function as conventional electrical relays, but is said to have a lower cost of manufacture than conventional types while at the same time providing increased sensitivity and reliability. Printact is designed for almost completely automatic manufacture, eliminating the final adjustments entirely and reducing hand assembly operations to a minimum. It is particularly adapted for printed circuits.

Basically, the relay is made up of two parts, a magnetic motor assembly and an armature and moving contact assembly.

The magnetic motor, molded in a high-impact plastic, consists of a ceramic magnet positioned between two u-shaped pole pieces made of No. 5 relay steel. The pole pieces are assembled with the magnet between them to form an E-shaped structure with a coil (wound on a nylon bobbin) surrounding the center leg. The armature is normally biased against one leg of the E by the permanent magnet. When voltage is applied to the relay, the flux produced by the coil tends to attract the other end of the armature across the open air gap, at the same time bucking the flux of the permanent magnet and tending to cancel the attractive force across the closed gap. Sufficient current through the coil will cause the armature to rotate; removal of this current permits the permanent magnet to restore the armature to its original position.

Use of a permanent magnet, whose restoring force tends to decrease rather than increase as the armature rotates, accounts for the high sensitivity and enhances the snap action of the relay compared to a conventional relay with a return spring.

The armature and moving contact assembly consists of a steel armature, a Mylar insulator, a high impact plastic molding, and heat treated beryllium-copper spring-blades with bar palladium contacts. In order to keep production costs down, it was necessary to eliminate spring-blade adjustment as a secondary operation. The solution was, in effect, to sandwich the spring-blade of a given geometry between two sections, one flat and one of a particular contour, deflect the spring and maintain this deflection at the precise point where satisfactory operation would be obtained, without further manipulation. Because of its long



Typical printed circuit board conductor configurations for the Printact relay.

time dimensional stability, beryllium-copper was chosen for the spring-blades. They are designed and produced with tolerances that are in the order of 0.001.

The balanced armature construction gives a high degree of freedom from shock and vibration which, together with the simplicity of the design and absence of hand adjustment, accounts for the high reliability of the relay.

Printact can be mounted as an integral part of a printed circuit board. Fixed contacts are eliminated entirely and the moving contacts which are part of the armature assembly are designed to mate with conductors on the printed board.

The preferred printed wiring base material is glass cloth epoxy although other materials may be used. Conductor material is 2 ounce copper, 0.0028" thick, and the contact areas should be placed with rhodium over nickel, although other board and contact materials may be used.

Operating voltage ranges from 6 to 24 vdc with corresponding coil resistances from 125 to 2000 ohms (±10%). At 24 volts dc, minimum life is 5,000,000 operations with a dry circuit contact load and 1,000,000 operations with a 0.5 amp resistive load. These ratings are based on the recommended printed circuit.

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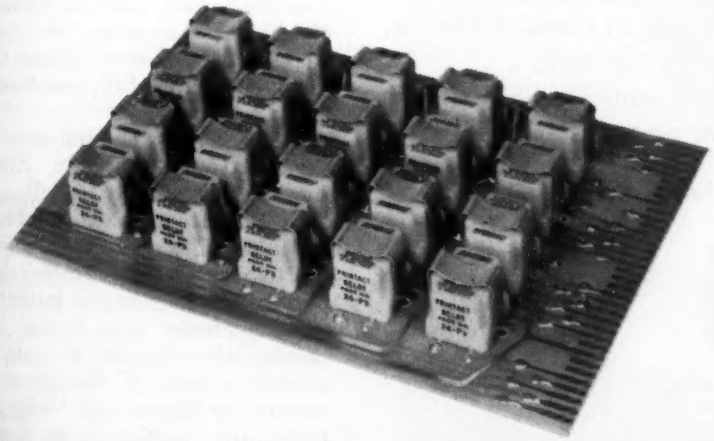

Individual memory module which registers up to 40 items of information in a doctor's register has 20 Printact relays occupying 8¼" x 5¾" x 1" of space. Using conventional relays, a system accommodating four hundred doctors requires 1,165 cubic feet of space. Redesign of the system to employ the new Printact relays reduced the equipment volume requirement to 345 cubic feet. Among other products in which Executone has obtained improved design and performance using the new relays are intercommunication and industrial data acquisition equipment. In addition, Printact is said to offer great potential in the design of all-relay printed-circuit telephone switchboards and low-cost digital computers.

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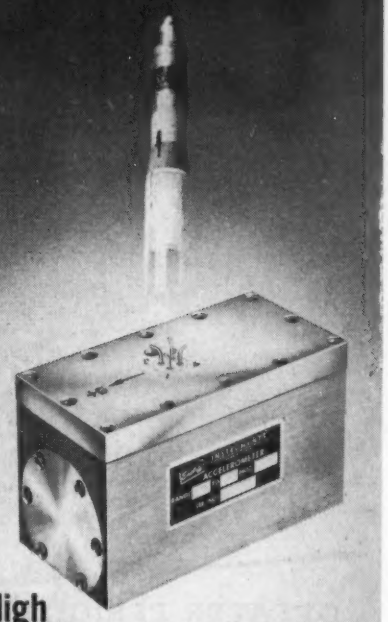

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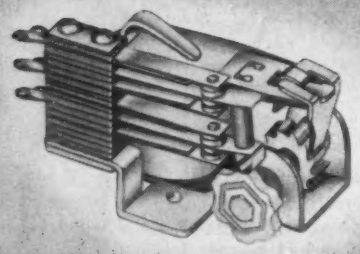

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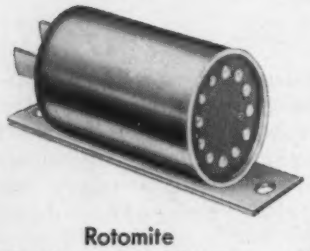
Write for information on these and other Guardian Controls



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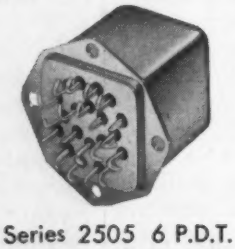
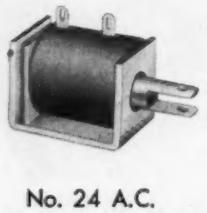


Series 2505 6 P.D.T.
Hermetically Sealed Relay



No. 24 A.C.
Midget Solenoid

GUARDIAN ELECTRIC
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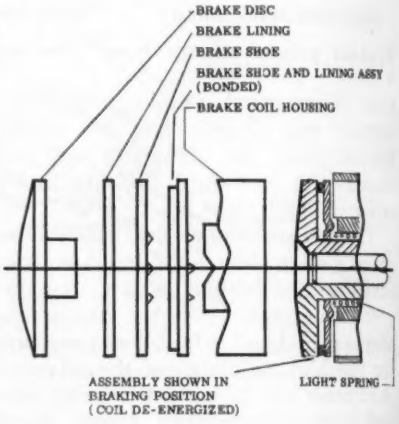
CAM-ACTION BRAKE

Unit Stops Motor in One-Tenth the Usual Time

Fast-stopping time of a cam-action motor brake is accomplished by four accurately formed dimples that register in four precision shaped grooves. The dimples provide the additional function of locating and centering the brake shoe, thus eliminating the problem of locating pins and other expensive devices. Stopping time and/or the static holding torque can be varied by changing the angles of the dimples and the grooves.



Tests were conducted using a brake of approximately one in. in diameter, in conjunction with a 1⅛ in. diameter permanent magnet dc motor. The motor armature was approximately ¾ in. by 1 in. long, with armature speed of 24,000 rpm. Actuation of the brake stopped the armature in less than two revolutions from full speed of 24,000 rpm.

Operation of the cam-action brake, developed by American Electronics, Inc., L.A., Calif., is as follows: when the coil is de-energized, the brake shoe is pushed into contact with the brake disc which is affixed to the shaft in a positive manner. At the instant of contact, the brake shoe begins to rotate causing the dimples to ride up the slanted surface of the housing. This cam-action causes high loading on the brake disc, forcing it to a complete stop.

Excessive sliding is eliminated thus reducing brake lining wear which extends functional life. The company reports that the brake can stop a motor in one tenth the time required by conventional braking systems. • • •

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WORTH FILING

Voltage Regulators

Providing complete specification data for 2,020 standard magnetic voltage regulator models, and eight page handbook contains information to guide users in selecting and using regulators in dc power supply design. Electrical and physical characteristics are shown in a large, fold-out chart.

Source: Raytheon Co.
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Resistance Welding

Pocket slide chart provides finger-tip accessibility to pertinent resistance welding data including the selection of the proper electrodes for joining many commonly-welded ferrous and nonferrous alloys, determination of the proper spot welding and seam welding schedules for various thicknesses of low carbon steel with a conversion table for other alloys and accurate heat balance instructions.

Source: Ampco Metal, Inc.
Milwaukee, Wis.

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Spectrum Analyzers

Eight-page brochure explains the principle of operation and gives complete specs and diagrams on spectrum analyzers. Units provide complete spectrum analysis at rates as high as 200 times per second with resolution maintained at 0.7 percent to 3 percent of the band for two equal-amplitude signals. Designed to operate in several ranges from 20 cps to 100 kc, the models employ either 100 or 420 filter elements for high-speed, high-resolution frequency analysis.

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Comprehensive guide to ultrasonic cleaning, entitled "How to Clean Ultrasonically with Self Tuning," provides a basic explanation of how ultrasonics works, what it can do to provide the safest and most consistent cleaning performance and an aid to selecting the correct tank and generator sizes or console model. Discussion on the Autosonic cleaner outlines how the new equipment, which tunes itself without operator attention, maintains maximum efficiency never before available.

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SYSTEM APPLICATIONS OF SHAFT ANGLE ENCODERS

V-Scan Logic Design

by **A. R. Roth** *Litton Systems, Inc., Beverly Hills, California*

A fundamental problem in the application of digital shaft angle encoders is how to resolve the ambiguity at the transition points between digits. Two general approaches may be taken: development of special binary codes which change only one digit at a time, such as the familiar Gray code, or use of brushes, selected by logic circuitry to avoid ambiguity.

The principal disadvantage of the first approach is the need to convert Gray code to a more natural computer language for use in digital equipment. Most encoders use the second solution which is called "V scanning" because of the "V" pattern of the brush arrangement. Logic circuitry is required to select the brush that is to provide the output for each track. This logic is designed so that a brush is never called upon to provide an output while resting on a transition edge. In this way, ambiguous readouts are prevented.

V scan logic can be performed by an external circuit or by self-contained circuits. The external selection scheme gives the external scan encoder many advantages over a self-selecting encoder in any but the simplest system as the following discussion of their relative merits will show.

The self-selecting encoder is generally more efficient in a system having only one or two encoders providing time-shared parallel outputs because in these applications it requires a minimum of external circuitry. If, however, the system has either a serial digital output or more than two encoders, or both, the self-select system is less efficient because of the amount of external circuitry required. The external scan encoder, on the other hand, uses a relatively constant amount of circuitry regardless of the complexity of the application.

The self-selecting encoder is not efficient in a serial system because it requires an external serial time selection matrix. Such timing can be readily included in external V scan circuits. It requires much more equipment in a time-shared multiple encoder system, regardless of whether the system requires serial or parallel information because it does not have built-in diodes for isolation between encoders. The diodes must be added externally. Also, the first digit of each encoder requires special external circuitry.

Other disadvantages of the self-selecting encoder are:

- The code pattern is very complex by comparison with that of the standard V scan pattern. Four brushes per digit are required instead of two. For this reason, a reliable self-selecting encoder cannot be made as small as an external scan unit.
- Friction and wear are generally greater because there are twice as many brushes.
- Internal decoding is handled in such a manner that a loss of the least significant track causes complete loss of information. In an external V scan unit, the information is available to half the accuracy in the event of failure of the least significant track. The least significant track is most likely to fail because of its high resolution.
- It doesn't lend itself readily to low voltage transistor systems, especially in a 13- and 18-bit unit. In these encoders, the addressing pulse enters the least significant digit and proceeds serially through all the internal selection diodes. In the 18-bit encoder, the serial drop in 17 diodes could be as high as 12 volts with silicon diodes; 8 volts for germanium diodes. This means that a 15- to 25-volt addressing signal should be used for reliable operation. External scan encoders, by comparison, are often addressed with 3-volt signals and with ample margin. Here only one diode is in series between input and output.

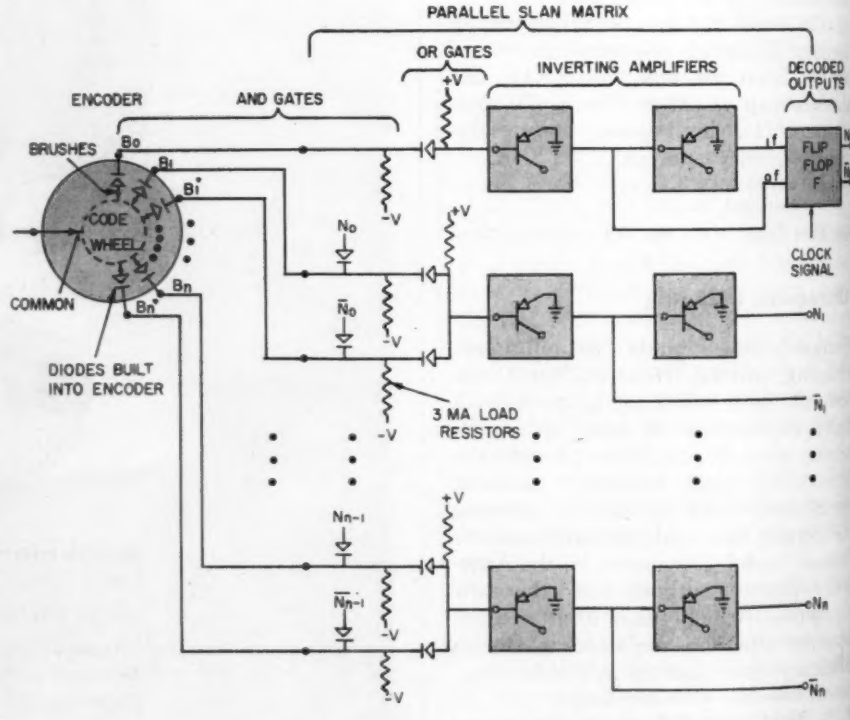

Fig 1 Parallel V-scan matrix.

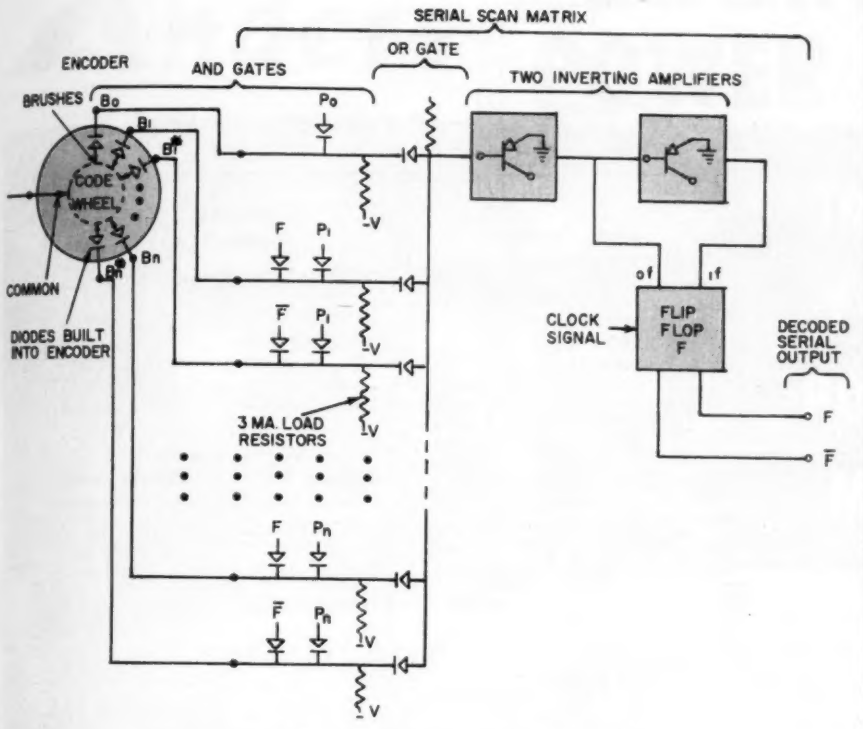

Fig 2 Serial V-scan matrix.

EXTERNAL V-SCAN LOGIC

In designing externally selected V-scan logic to eliminate ambiguity in a double brush system, it is necessary to determine which of the two brushes available shall be sensed to determine the value of a particular track. This decision is based on the binary value read from the previous track. Hence, the state of the previous bit determines which brush of the next pair is to be examined. For example, if the N track is a "zero," then the leading (B^*) brush for the N + 1 track would be examined. Conversely, if the N track reads "one," then the lagging (B) brush would be examined for the N + 1 track.

The logic required is:

$$N_n = \overline{(N_n - 1)}\, B^*_n + (N_n - 1) B_n$$

where

N_n = the value of the n track,
$(N_n - 1)$ = the value of the n-1 track,
B_n = lagging brush for the n track,
B^*_n = leading brush for the n track.

This V-scan logic is performed by an external scan matrix which may be designed to operate in serial or parallel. The parallel scan matrix requires separate diodes and amplifiers for each brush pair so that all brushes can be processed at the same times. Fig 1 shows a parallel mechanization of the scan logic for a hypothetical 10-bit encoder. The amplifiers indicated are one-transistor, common-emitter "in-

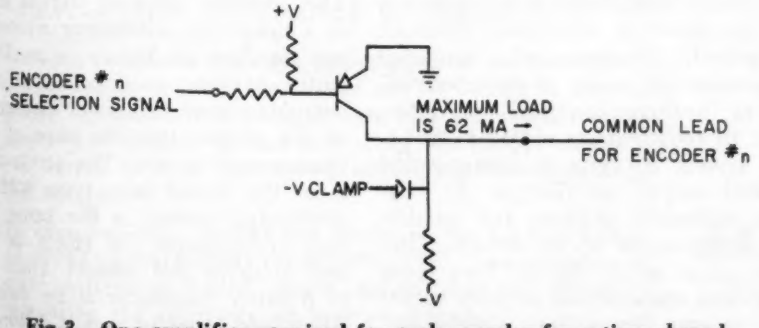

Fig 3 One amplifier required for each encoder for a time shared matrix. A sufficiently negative voltage input turns the transistor on, its collector rises to ground potential and the encoder is activated.

General Electric RTV*

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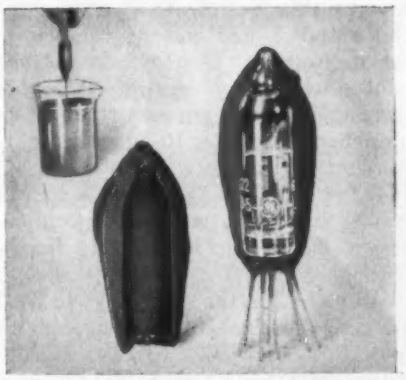

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verting amplifiers."

Six diodes and two of the transistor inverting amplifiers are used to create the output signal and its complement for each track. The first, least-significant track has only one brush which is read directly through two transistor amplifiers. Thus, a 10-bit encoder requires 20 transistor amplifiers.

Output from the parallel scan matrix can be fed into a computer in either a serial or a parallel mode. If a parallel readout is desired, sufficient time must be allowed for the amplifiers to settle because the signals ripple through the matrix. This is similar to a carry propagation problem. Output from the first track can be stored in a flip flop to prevent the value from changing during a reading. When this is done, a total of two bit times are required to energize and read an encoder.

A serial scan matrix can be used where a serial readout to the computer is used. The serial scan matrix has fewer parts because the brush-pairs are processed one at a time. Only one set of amplifiers is required to read the entire encoder (Fig 2). A flip flop is used to store the values of the brush-pairs after they are determined. Output of the serial matrix is read from the flip flop. The "p" signals shown in Fig 2 are sequential timing signals which gate the brush-pairs to the flip flop inputs one at a time. They are usually generated by the central computer.

The flip flop holds the value of the previous brush-pair. Thus, $(N_n - 1)$ and $\overline{(N_n - 1)}$ in the scan equations are now represented by F and $\overline{F}$ respectively. The corresponding equations for a set-reset flip flop are:

$$0^f = P_0 B_0 + P_1 B_1 F + P_1 B_1 F + \cdots + P_n B_n F + P_n B_n \overline{F}$$

0^f = the complement of the 1 f equation

where n is the number of encoder bits minus one. These equations are mechanized in Fig 2.

The above mentioned scan matrices are shared by all encoders. Only one matrix is required per machine. Time sharing is readily accomplished because the external select encoders have isolation diodes built in. It is only necessary to connect all corresponding wires from many encoders together and bus them to the scan matrix in the computer. Each encoder can be interrogated by energizing its one "common" lead. This applies voltage to the code wheel for that encoder. All connecting brushes pass the voltage on the scan

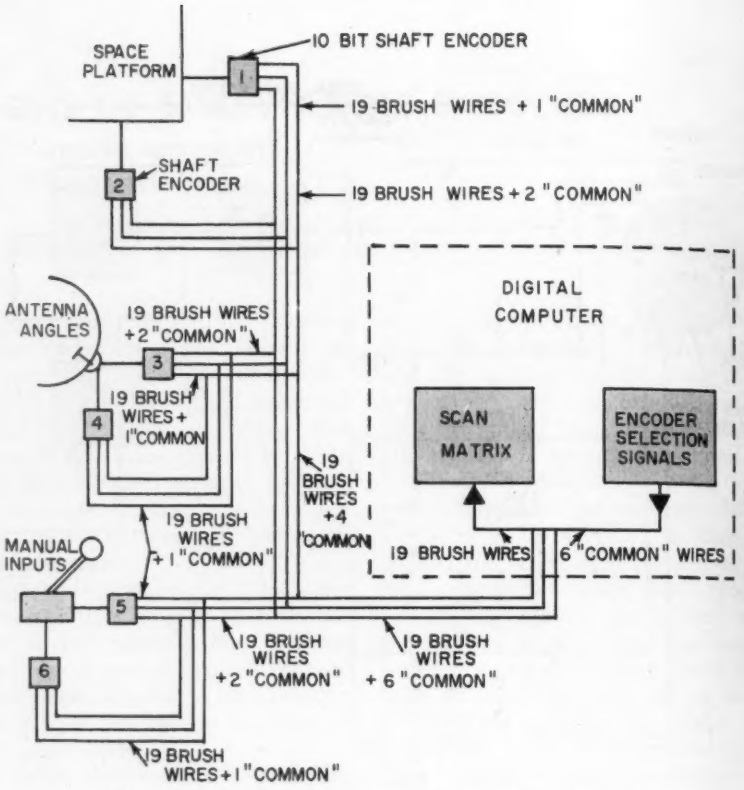

Fig 4 Using shaft encoders for computer inputs —illustrating sharing of wires by six encoders.

circuits. In the meantime, the "common" leads for all other encoders on the line are held "off," and the other encoders have no effect on the scan matrix. The encoders are, in effect, "ORED" together on common inputs.

The "common" signal is easily mechanized by passing the encoder selection signal into a one-transistor inverting amplifier. The transistor collector drives the encoder "common" wire directly. Fig 3 shows a typical grounded emitter transistor amplifier used to energize a Litton Industries 13-bit shaft encoder for outputting.

A 10-bith encoder would have 19 brush wires plus a "common" wire, for a total of 20 wires. The 19 brush wires can be tied together as illustrated in Fig 4, so that a minimum of wires enter the computer. Once an encoder system has been established, all that is required to add more encoders is one new "common" wire for each additional encoder.

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Checkout Equipment

Specifically designed for incorporation as the heart of electronic checkout equipment, transistorized, universal programmable, ac-dc multimeter/ratiometer analogue-to-digital converters meet all requirements of Mil-P-2664A. The system converts to binary-coded decimal output; ac voltages, dc voltages, resistance, in-phase and quadrature components of ac voltages and ratios of ac or dc signals. Two types of systems are available to meet varied requirements. Epsco Inc., Cambridge, Mass.

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PNEUMATIC PRESSURE CONTROL

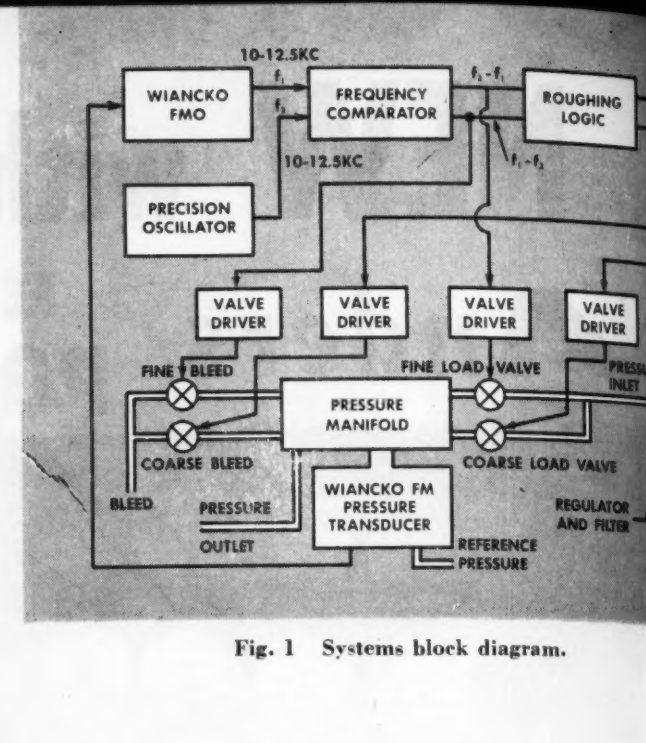

Fig. 1 Systems block diagram.

Accurate Regulation by a Digital Servo Network

Regulation and control of pneumatic pressure is usually accomplished by mechanical or electromechanical systems of the analog variety which have limited resolution, control tolerances and stability.

In a paper presented at the Sept. 1960 Joint Automatic Control Conference, Mr. O. K. Kowallis, Director of Research, Wiancko Engrg. Co., Pasadena, Calif., described a digital servo system for pressure control in which resolution can be set as fine as required without significantly sacrificing the response characteristic. The error of the control portion of the system converges to zero as time goes to infinity.

SYSTEM DESCRIPTION

The block diagram shown in Fig 1 presents the major system elements. The feedback control loop includes the following components:

- Frequency modulated pressure transducer
- Frequency modulated oscillator (FMO)
- Frequency comparator
- Valve drivers
- Control valves
- Pressure manifold volume

A pressure change in the manifold enters the control loop at the pressure transducer and oscillator (FMO) and is converted to a frequency change. This frequency deviates in direct proportion to the manifold pressure. The incremental frequency change is 2500 cps for a pressure change from zero to full scale. In order to program each new pressure point, a precision oscillator is set to a new frequency and the remainder of the servo loop acts to cause the FMO frequency to match the precision oscillator frequency. This is accomplished by changing the pressure in the pressure manifold in the appropriate manner.

The precision oscillator may be switched to any number of preset frequencies between ten to 12.5 kc; ten kc is the zero pressure frequency and 12.5 kc is the frequency for full scale pressure. A variety of intermediate pressure points can be obtained.

Output frequencies of the two oscillators are fed to the frequency comparator which answers the simple question as to which of the two frequency inputs is greater. The answer is presented on one of two sets of output terminals as a pulse train whose rate is based upon the frequency difference of f_1 and f_2. The position of the pulse train on the output leads of the frequency comparator is determined by whether $f_1 > f_2$ or $f_2 > f_1$. This output is the error signal upon which the system operates.

EQUIVALENT CIRCUIT

In Fig 2, the pressure source P_s is set to 110% of the maximum chamber pressure P in order to minimize response time. R1 and R2 are flow restrictions in the pressure line. V-1 and V-2 represent pneumatic valves which are normally closed. As V-1 is opened, the source pressure P_s is connected to the pressure manifold C through flow restriction R1; the chamber pressure P rises, approaching P_s in an exponential manner. The chamber pressure P is sensed and this information controls V-1 so pressure P will not exceed a pre-set demand value. If P is greater than a pre-set value, the detecting system will cause V-2 to open until sufficient pressure is bled off and P equals the demand value. V-1 and V-2 control the fine load and bleed restrictions respectively.

The required pressure change per valve-cycle is less than 1/5000 of the maximum value of P causing the response time of the system to be excessive. In order to shorten the time required for the system to balance, roughing valves V-3 and V-4 have been provided to control flow restrictions R3 and R4. R3 and R4 are set so they have approximately 1/50 of the flow resistance of R1 and R2 respectively.

ROUGHING LOGIC AND VALVE DRIVERS

The addition of course controls to the system to provide increased system response presented a problem. It was essential that these roughing controls be turned off at precisely the proper time. If these controls stay on too long, the system overshoots the control point. If they turn off too soon, the time required for the system to balance is unduly extended. Therefore, precise turn-off points, accurate to a few parts per thousand, had to be established. A block diagram of the roughing control logic is shown in Fig 3.

Fig 4 shows a frequency characteristic of a one-shot multivibrator for various pulse input rates from the frequency comparator. As the input pulse rate is varied from zero to a value of 20 cps, the one-shot multi-

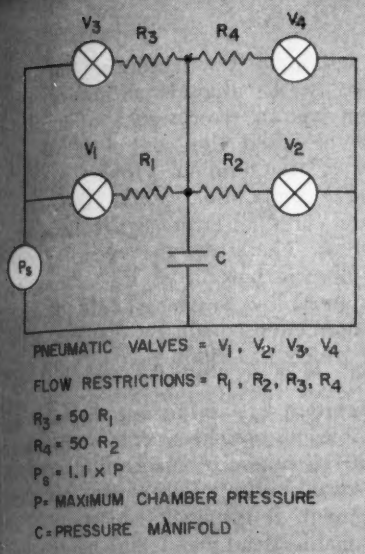

Fig. 2 **Equivalent circuit of the detecting sub-system.**

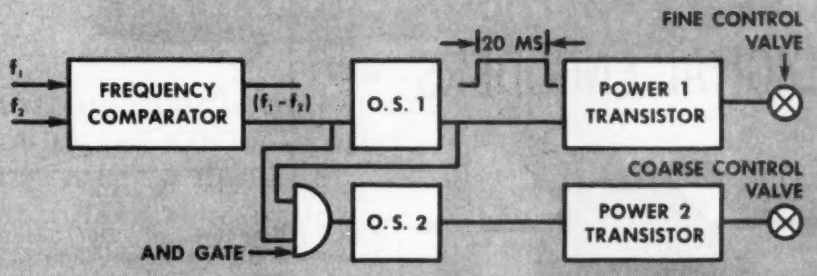

Fig. 3 **Block diagram of the roughing control logic.**

vibrator (O.S. 1) follows in a ratio of 1:1. As the pulse rate is increased above 20 pulses/sec, O.S. 1 divides by two or some larger integer. Each time the O.S. 1 is fired, it produces a 20 millisecond duration positive pulse. This positive pedestal is combined in an AND gate with the pulses from the frequency comparator.

The coincidence of a positive pedestal from O.S. 1 and the pulses from the frequency comparator trigger O.S. 2 and the coarse valve. Thus, the coarse control will be activated for all frequency comparator output pulse rates above 20 pulses/sec. When the frequency comparator pulse rate is less than 20 pulses/sec, O.S. 1 will operate in a 1:1 ratio. As no pulse can occur on the positive pedestal under this condition, the coarse control is cut off for all valves under 20 pulses. The fine and coarse control branches are identical with the exception of the AND gate.

Above ten pulses/sec, the current impulses are integrated by a control valve and the valve is fully open. Below ten pulses/sec, the valve will cycle in direct proportion to the input pulse rate and will approach the terminal control point exponentially. All four of the control valves operate in this manner.

STANDARDIZATION AND OPTIMIZATION

Bleed and load curves of Fig 5 illustrate the response of the fine controls. The highest rate of change of pressure occurs when Δp across the flow restriction is maximum. In an incremental control system, the smallest incremental change should be insignificant in respect to the resolution required. In this system, the desired count resolution is 1/2500, therefore, an incremental step of 1/5000 of full scale pressure was selected.

The coarse and fine flow restrictions have been made adjustable so optimum response can be obtained with coupled volumes added to the pressure manifold volume. Generalized system response is shown in Fig 6.

DETECTION OF SYSTEM LEAKS

One of the prerequisites for accurate pressure simulation is to minimize flow in the system so that all pressures are due to static pressure only. The accurate measurement of system leak rate is essential to assure accurate pressure calibration.

The system can easily detect a leak rate of 0.002 cubic inches/sec., referred to full-scale chamber pressure. This leak rate can be observed directly on an error indicator as one pulse/sec which drives the fine loading control. If the system leak rate is less than this value, it will normally produce a negligible pressure drop in connecting lines. In cases where greater resolution is required, the power to the control valves may be switched off and the system will indicate the time integral of the leak. In this manner sensitivity may be extended as necessary, limited only by random thermal effects and the stability of the system.

SYSTEM ACCURACY ANALYSIS

Analysis of system accuracy is relatively simple after balance has occured. It is limited to the following components:

- Quarts crystal in the precision oscillator
- Digital servo
- Pressure transducer and FMO

The precision oscillator's long term stability without temperature control is 0.004%. The error of the frequency comparator, valve drive units, etc., rapidly converge to a negligible quan-

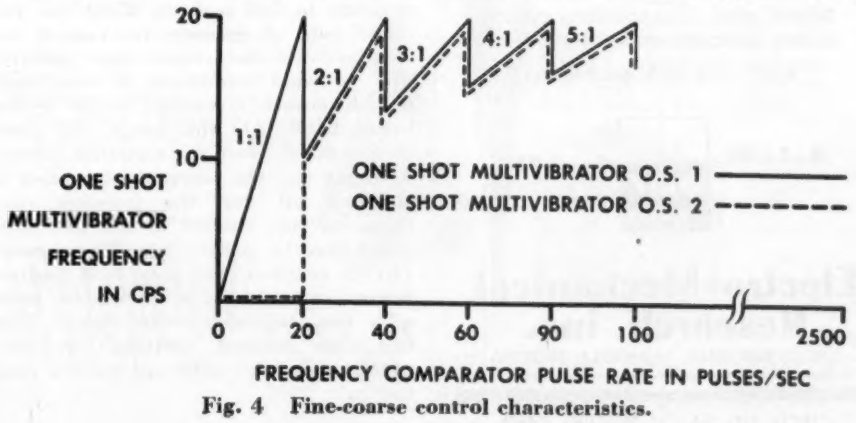

Fig. 4 **Fine-coarse control characteristics.**

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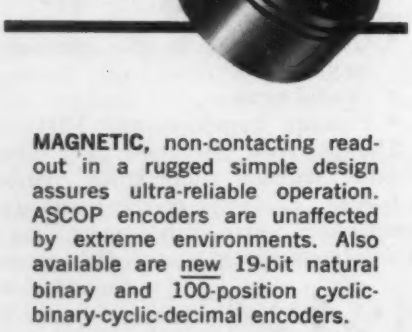

MODEL 505A:
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MAGNETIC, non-contacting readout in a rugged simple design assures ultra-reliable operation. ASCOP encoders are unaffected by extreme environments. Also available are new 19-bit natural binary and 100-position cyclic-binary-cyclic-decimal encoders.

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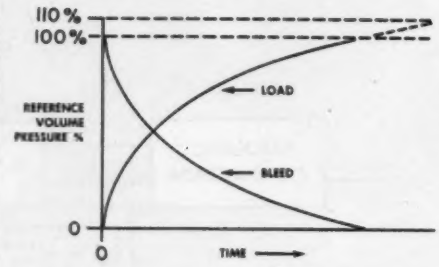

Fig 5 Response of fine controls. Under the highest slope condition, the bleed and load restrictions are set so one valve cycle produces a frequency or pressure change in the pressure manifold of 1/5000 of full scale. In this manner, the proper compromise is obtained between system resolution and response for the fine controls.

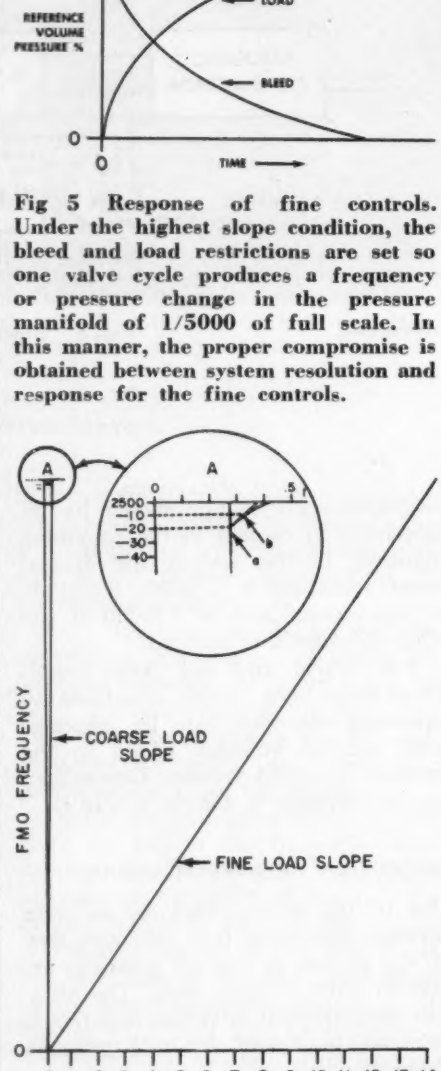

Fig 6 Generalized system response. Various control characteristics combine to determine the overall system response. If a step function demand is placed on the system for increased pressure to full scale or 2500 cps, the initial rate of pressure increase is determined by the coarse load control. The pressure continues to rise until the difference frequency is 20 cycles below 2500. (At this point, the pressure is 0.8% from the terminal value). At point (a) the coarse load control is switched off and the pressure continues to rise, limited by the fine load restriction to point (b). When point (b) is reached, the fine load control begins to cycle on a one-to-one basis with the frequency error signal. This two stage control technique provides rapid response with adequate resolution.

tity within a few seconds. For example, if the digital portion of the system has an error signal input of 1 cycle/sec, then the control is within 0.04% of the terminal value. The frequency comparator senses the time integral of the error signal between f_1 and f_2. Therefore, the overall accuracy of this portion of the system is determined by the magnitude of the step corrections made by the fine controls which is 1/5000 or 0.02% of full scale.

A certain amount of dead band is desirable in normal operation of this system to minimize mechanical cycles and extend the useful life of the equipment. It is possible to provide a controllable dead band and cause the system to respond to the magnitude of the error term rather than the time integral of the error term. This is accomplished by introducing directional locking from the precision oscillator to the FMO. The two units then have the same frequency until the pressure error signal is equal to or greater than ½ cps. At this point, the oscillators unlock and error correction is made by the digital servo. In this manner, the system responds similarly to an analog servo system, however, the dead band is controllable and can be made as small as desired.

The desired objective of the system design was to limit the error accumulation to the least number of sources and to exercise maximum effort to control them. The discussion above reveals that the primary error source is limited to the pressure transducer and FMO. Significant progress has been made in the design of these components such that the long term stability of the two components in combination is now equal to or better than 0.05% per week. Thus, the overall system accuracy is in the order of 0.05% of pressure range.

Another point which should be reviewed briefly is the effect of temperature change on the pressure manifold volume. As long as the temperature rate of change of the reference gas is sufficiently slow, the system will compensate in the appropriate manner. Fortunately, most systems have large thermal time constants, thus providing response capability sufficient to correct any variations due to ambient temperature change.

SYSTEMS PACKAGE

Wiancko Engrg. Co. has incorporated the system into a packaged unit called a Digital Pressure Generator (Fig 7).

The unit is a single channel model having only one pneumatic pressure module. Racks are available for mounting four additional pneumatic

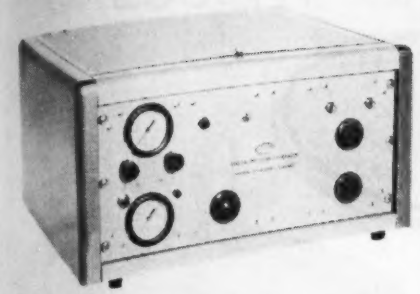

Fig 7 Range of application of digital pressure generator extends from the simple portable set-up for rapid field calibration of pressure gages to fully automatic systems for complete checkout and calibration of pressure instrumentation systems.

modules and convenient switching from one range to another is provided. Either five or 11 crystal reference checkpoints are available and can be selected to produce ten or 25% steps of pressure based on the full scale pressure range selected. An external input is also provided so that external frequency sources may be used for control of the unit.

APPLICATIONS

The system has many applications but the primary ones are control of pressure and programming fixed pressure points. Programmed pressure-time curves may be obtained by introducing a precision oscillator frequency derived from a magnetic tape loop or by selecting appropriate time delays and crystal reference points. Any type of a variable function may be constructed in this manner. The only problem which need be considered is the response of the system in cases where rate of change of reference frequency becomes too great. The regulated pressure will follow exactly the reference frequency input within the limits set by the response of the system.

Ground handling equipment for aircraft and missiles require pressure sources of high accuracy which can be programmed with other parameters for vehicle checkout.

Wind tunnel tests often require large ambient interior pressure changes during normal operations and these changes cause difficulty in measuring low range pressure variations.

Other applications for the system include: simulation of altitude and Mach conditions for air data computers; verification of leak integrity of a closed system; calibration and checkout of telemetering systems. In industrial manufacturing and production processes, the system is used for the automatic calibration of pressure switches, transducers, indicators and many other components.

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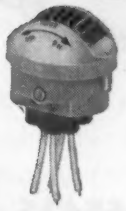

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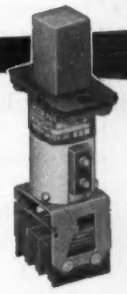

3 Pole Switch with Solenoid Coil, which holds depressed pushbutton in the "on" position until solenoid releases. Used in jet fighter-bomber.

Alternate Action Pushbutton Switch with double-pole, double-throw circuitry. This assembly is an example of the Haydon Standard Series which includes momentary as well as push-push action.

HAYDON Pushbutton Switches are 2 to 6 pole, double-throw; actuating buttons available in three colors; terminals—solder hole, turret, or double turret; use HAYDON Series 5300 snap-action switches.

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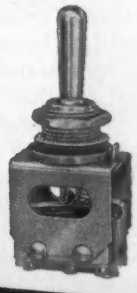

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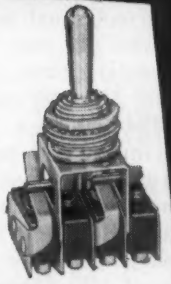

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HERMETIC SEALS

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Packaging requirements for many electronic "black boxes," instruments and other devices, military as well as commercial, call for hermetic sealing that meets Grade A Mil-S-8484 specification.

Heretofore this sealing has generally been accomplished by welding, soldering, or brazing, or use of epoxy or other specific plastic—all of which mean a solid seal. Such seals limit accessability to a minimum. They are also subject to failure from high G loads, vibration, and they often involve costly manufacturing techniques.

Recent tests conducted by a Parker Seal Company research and development team have shown that this specification can be met with a mechanical seal of the molded-in-place type where proper compound is used and volume/void ratio is carefully controlled.

In these seals, commonly known by the trade name Gask-O-Seals, rubber (or elastomer) is molded directly into a groove in a metal part which conforms to the area of the flange to be sealed (see Fig. 1). The rubber and the metal part (called a retainer) act integrally.

Seals of this kind had been used by the missile industry to meet hermetic specification Grade A Mil-S-8484 and had been evaluated for that purpose by independent test laboratories. Parker Seal engineers noted that on certain seals the leak rates obtained were consistently lower than required by the specification. They decided therefore, to investigate the whole field thoroughly. Results of the research program, as described by John R. Jordan, Parker Seal Research Engineer, should be of interest to those concerned with any aspect of hermetic or hi-vacuum sealing.

The leak rate test results qualifying the seals for the missile industry had been determined by extrapolating information obtained after one hour of continual testing to cubic centimeters of air per inch of seal per year. Table I shows results obtained using this standard time.

All the seals except those containing Viton-A compound and silicone rubber passed Mil-S-8484 Grade A Seal requirements; that is, the leak rates were less than one cubic centimeter of air per inch of seal per year. However, Parker Seal Engineers noted that the leakage rate was increasing slightly at the end of the hour test. Realizing that designers who specify hermetic sealing generally require stable conditions over long periods of time, they recognized that a one-hour test for rubber or other organic seals was not adequate. Such tests are acceptable for welded, brazed and soldered assemblies because the only leaks important enough for consideration are mechanical leaks which stabilize almost immediately. Longer tests are necessary, however, when the leak rate is time dependent. They reasoned that complete solution of the gas in the rubber must take place before gas permeability becomes stabilized. A project was therefore initiated to determine the stabilized leak rate in a Gask-O-Seal containing B318-7 butyl rubber compound.

Fig 1 Some of the complex configurations of molded-in-place seals. These one-piece mechanical seals often provide numerous barriers for sealing off components allowing considerable freedom of design and lower manufacturing costs while allowing full serviceability.

TEST PROCEDURE

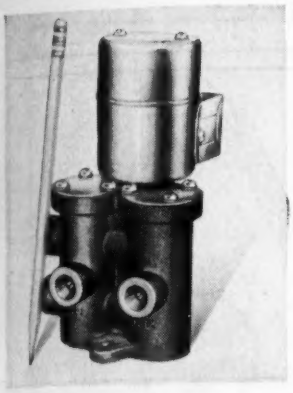
Gask-O-Seal containing B318-7 rubber molded in aluminum retainers were fastened into place in a test fixture which permitted flooding the exteriors of the seals with helium while drawing a 0.02 micron vacuum on the inside of the seals. The mating flanges on which the seals registered had a standard (125 RMS) machine finish. Each seal tested was 7.3 inches long and was fastened into place by four 8-32 screws torqued to 40 inch pounds.

TABLE 1

One Hour Leakage Rates For Gask-O-Seals

COMPOUND No.	POLYMER TYPE	LEAK RATE (Cubic Centimeters Air/Year/Inch)
B318-7	Butyl	0.15
B480-7	Butyl	0.20
B482-7	Butyl	0.34
N304-7	Nitrile	0.65
C408-7	Chloroprene	0.79
V411-7	Fluorinated Rubber	7.25
S455-7	Silicone	Greater than capacity of leak detector

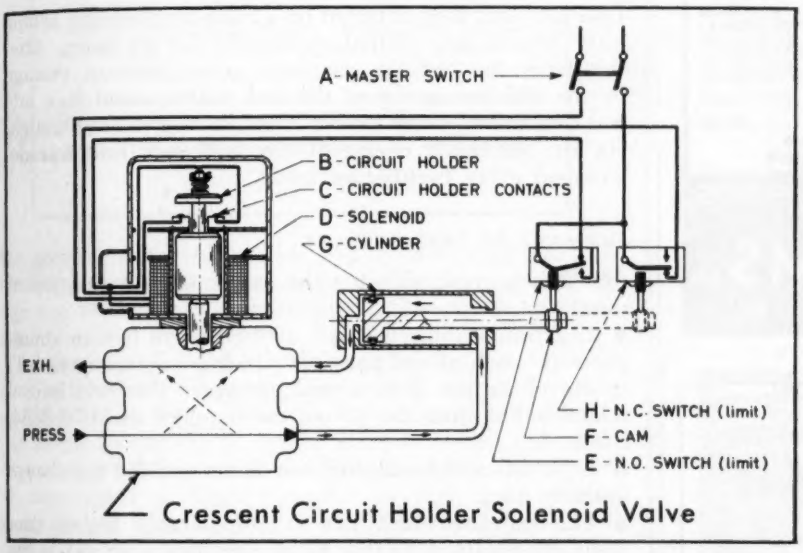
CRESCENT® CIRCUIT HOLDER SOLENOID VALVE



Compactness is an advantage of the unit.

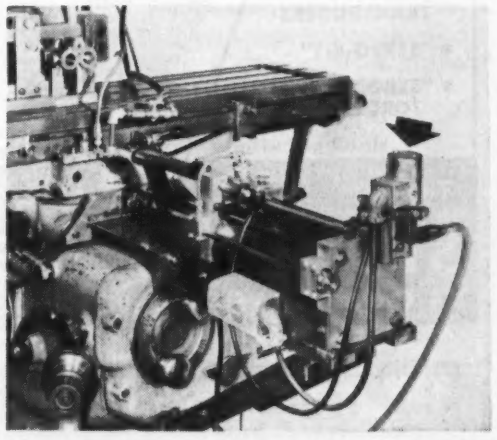
to make cycling operations fail-safe

This new solenoid valve revises standards of circuit holder dependability on automatic cycling machines. Circuit holding action is performed by a specially designed, heavy duty solenoid (tested for 100-million cycle operation under conditions many times more severe than those encountered in any industrial application). Use of relays is unnecessary (see diagram), thereby eliminating one electrical circuit and avoiding an additional possible source of trouble. The Crescent Circuit Holder Solenoid Valve is applicable to automate machine tools, packaging machines, conveying machines, etc. Write for complete information and specifications (Bulletin No. 60809), or let a Barksdale representative demonstrate how Crescent Valves can save you money by cutting downtime.

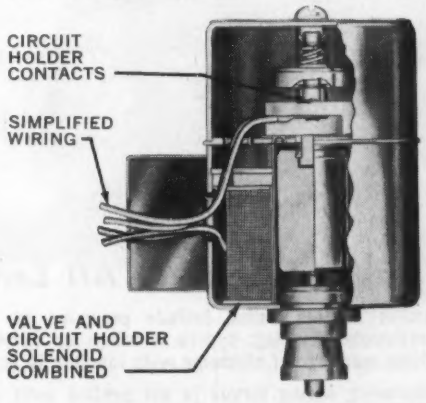


Crescent Circuit Holder Solenoid Valve

In the starting position, the master switch is open, solenoid is de-energized and normally open switch is closed by cam. When master switch is thrown, the solenoid is energized. Air flow through the main valve is reversed and cylinder moves to extended position (dotted line). As cylinder rod moves, switch (E) opens; circuit holder (B) and switch (H) maintain the circuit. When rod is fully extended, cam opens switch (H), de-energizing the solenoid and reversing air flow. Piston returns to starting position. When cylinder rod is fully retracted, the solenoid is re-energized by closing of switch (E), and the cycle is repeated until the master switch is opened.



Typical installation of the new Crescent Circuit Holder Valve (arrow) on a milling machine set up for a boring operation.



The valve solenoid, which is designed to outlast the life of the valve, performs the circuit holding function.

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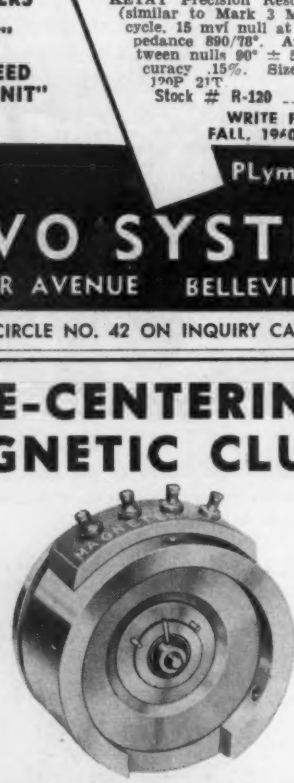

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Features of this clutch include provision of a cavity for potentiometer winding, syncro windings or switches. This facilitates marriage of clutching with function to be performed.

Re-centering spring torque is not applied until clutch is disengaged. Operational torque is thereby kept to an absolute minimum, making the unit ideal for gyroscope pick-off applications. Dual winding coil construction permits 12 or 24 volt operation, depending on application.

Material and processes in the manufacture of parts meet Mil Specifications.

For complete technical data write for Specification Sheet No. 1509-8A.

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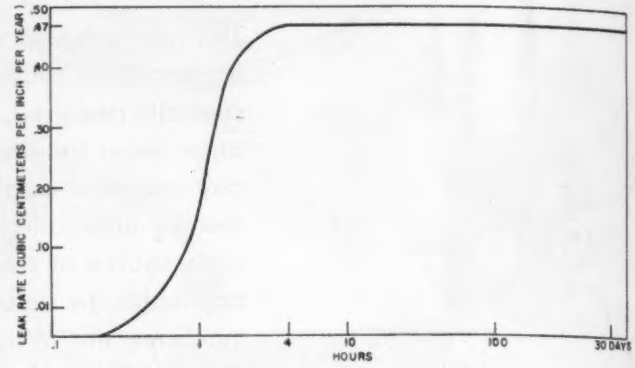

Fig 2 Leak rate of B-318 Butyl molded-in-place seals.

Leak rate was then obtained on a mass-spectrometer helium leak detector and plotted continually for six hours. After this time, the test jig was kept under constant vacuum by the diffusion pump in the leak detector and leak rate was determined every twelve hours for one week. Throughout the remainder of the 30-day test, leak rate was determined every twenty-four hours.

SUMMARY OF TEST RESULTS

Fig 2 is a graph showing the leak rate as a function of time.

- Leak rate stabilized at 4×10^{-8} cu cm of helium atmosphere per inch of seal per year which is equivalent to 0.47 cu cm of air per inch of seal per year. This rate is considerably less than the 1.0 cu cm required in Mil-S-8484, Grade A.
- Leak rate stabilized after four hours and did not change in thirty days.
- The stabilized leak rate is considerably higher than originally obtained (Table I) at one hour.

Effectiveness of the molded in place hermetic seal is dependent on two things: selection of the right rubber compound and proper geometry of the seal.

The rubber material must be selected on the basis of low permeability. In this respect, butyl compounds, as a generic class, are considered the best for "molded in place" seals. Permeability varies from one butyl compound to another, however, depending upon the nature of the fillers and curing agents used. Consequently, attention should be given to selecting a butyl compound with proven low permeability.

The second requirement—the geometry of the seal—must be carefully controlled to prevent movement of the seal which would result in excessive rate of mechanical leakage and to insure high compressive stress when the seal is tightened. When rubber is highly compressed it is less permeable than when it is in tension stress. Moreover, high compression increases the stress between the flange surface and the line of sealing contact, that is to say, the minor surface irregularities in the metal surfaces of the flanges are filled faster and more completely when the sealing material is under higher compressive stresses.

The best method of obtaining minimum lateral movement of the rubber and high compressive stress is use of controlled confinement. Controlled confinement in a seal means that the ratio of the compressed rubber volume to the available void volume is between 0.94 and 0.99; in other words, the volume of rubber is approximately 97% of

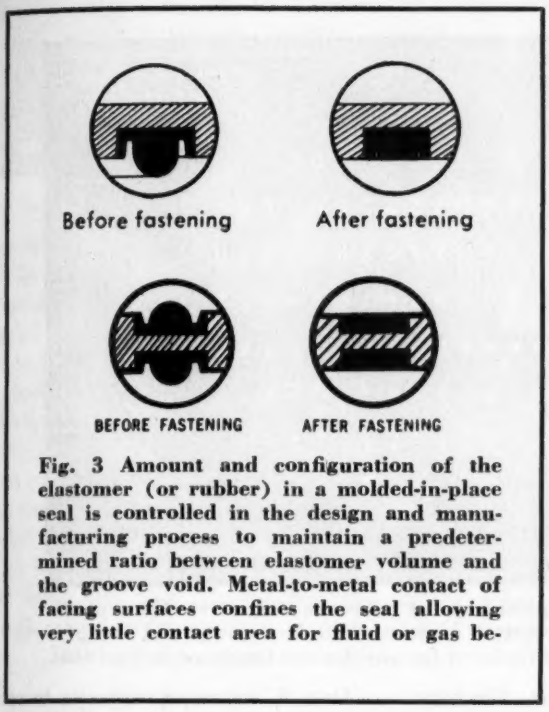

Fig. 3 Amount and configuration of the elastomer (or rubber) in a molded-in-place seal is controlled in the design and manufacturing process to maintain a predetermined ratio between elastomer volume and the groove void. Metal-to-metal contact of facing surfaces confines the seal allowing very little contact area for fluid or gas be-

the groove cavity volume, see Fig. 3. Attaining this relationship in a small groove requires intricate, careful design and manufacturing techniques for the molds and tooling.

In the field of vacuum processing of food, metals and chemicals, where the seal is required to separate a fluid and a vacuum, butyl rubber has fluid-resistance limitations –it swells excessively in certain fuels and chemicals. Furthermore, it does not resist the high temperatures frequently encountered in these processes. In such cases, special materials such as Buna-N, Chloroprene and fluorinated rubber can be used. Fortunately, such systems usually do not require Class A seals since the vacuum is regenerated by an outside pump.

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WORTH FILING

Designer's Fact Book

One-hundred-fifteen page revised edition of "Designer's Fact Book" includes property and application data covering 70 standard, special and molding grades of high-pressure thermosetting laminating plastics; military specs; a grade comparator chart and tolerance and weight specs.

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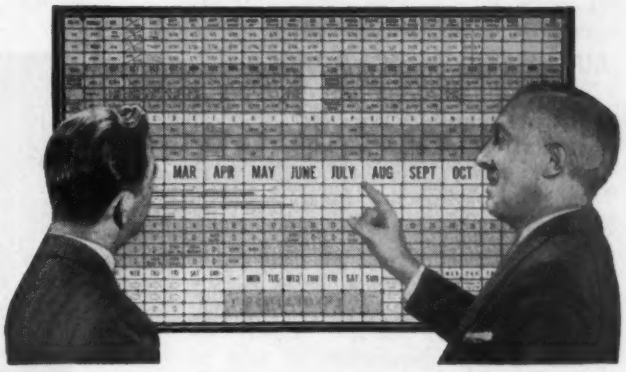

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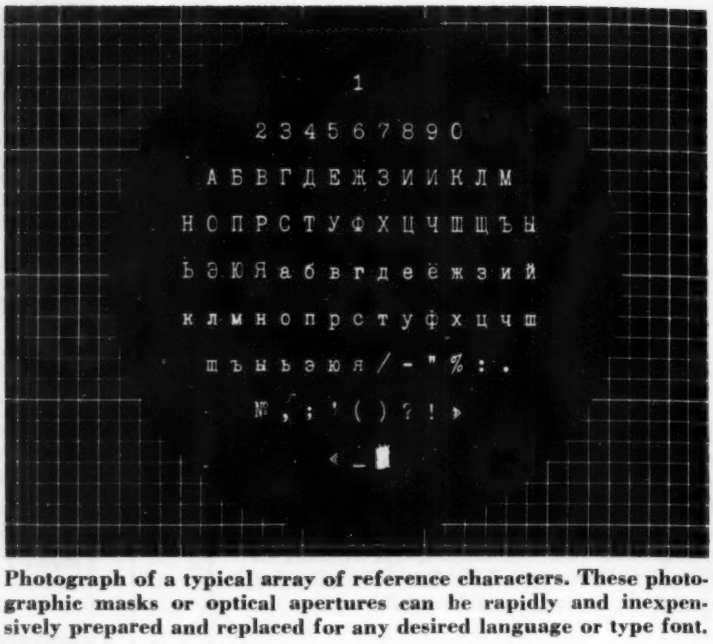
Baird-Atomic Inc. of Cambridge, Mass. has developed an optical-print reader which they claim to be inherently more efficient and less liable to confusion in the case of similar alphabet characters. The recognition operation is only a matter of a few millionths of a second and the speed of the reading, 1000 characters per second, is limited only by the method of presenting text to the machine. The instrument distinguishes a large number of different type fonts in various alphabets, including cyrillic and Greek characters. Recognition capability is independent of the spacing between lines, the position of the text on the printed page or the occurrence of randomly-interspersed graphic material.

Because of a multiplicity of problems associated with automatic print reading, Baird -Atomic has limited its efforts, for the present, to reading text which is first prepared on transparent 70 mm film. According to the company, the decision to work with photographic transparent text does not in any way preclude the possibility of reading opaque material directly.



Photograph of a typical array of reference characters. These photographic masks or optical apertures can be rapidly and inexpensively prepared and replaced for any desired language or type font.

OPERATION

Light from a lamp is transmitted through a diffuser and a lens onto an unknown transparent character. (If opaque copy is used, the optical arrangement would have to be altered but the following procedure would remain unchanged.) The light passing through (or reflected from) the unknown transparent character diverges and passes through an array of standard apertures and then to a corresponding array of photodetectors. Electrical outputs from each of these detectors can be processed and fed to a computer translator or to a recording tape for ultimate use with a translator.

Array of apertures includes all of the characters of interest. No motions, mechanical or electrical, are necessary to recognize and identify the unknown character. Consequently, the recognition technique does not limit the speed of operation. The speed is controlled by such factors as text alignment, poor copy, etc.

With only a slight increase in the optical complexity of the system, minor dissimilarities in characters and punctuation marks such as periods, commas and semicolons can be readily recognized. Baird-Atomic anticipates that appropriate identification of punctuation marks will be of primary importance in effective automatic translating.

One of the major obstacles to reaching a translating computer's top speed (Russian to English at 35 words per second) was the human operator's inability to feed more than 40 words a minute into the translator. The Baird-Atomic print reader operating at a rate of about 60 times as fast as a typist permits top speed operation.

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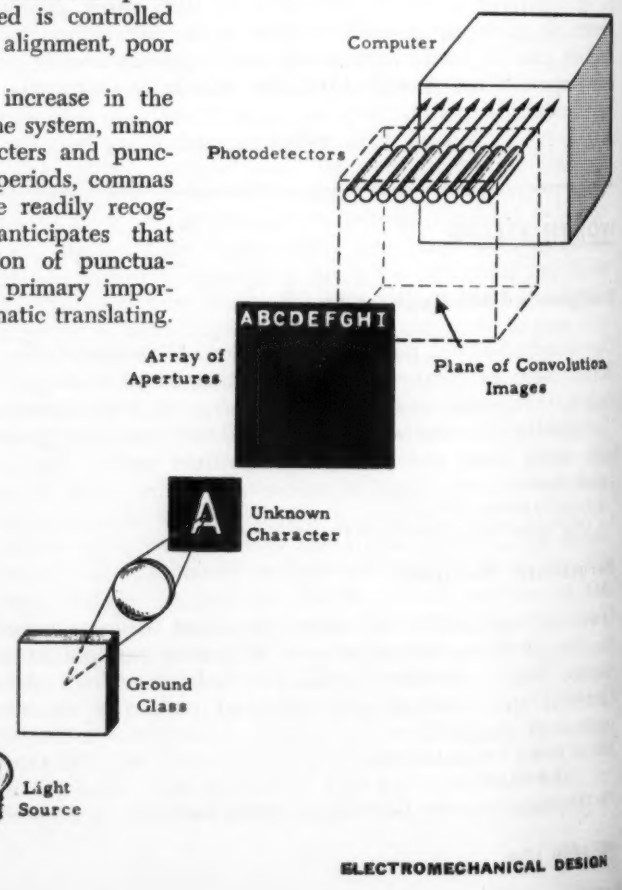
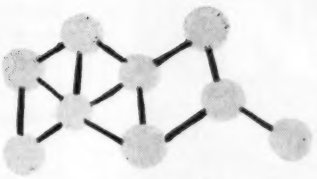


Schematic diagram of the Baird-Atomic print reader. Optical rays passing through the center of the unknown character "A" also pass through all the centers of all the characters in the reference aperture. If the letter "A" is the unknown, a bright spot appears in the plane in front of the detector for recognizing "A". This method simultaneously correlates all of the characters in a particular type font with the unknown character. Threshold circuits at the outputs of the photodetectors carry out the decision-making function.

by David Bandel *Staff Columnist*
Associate Technical Director,
TRACERLAB, INC.



MATERIALS

New Bearing Materials and lubricant developments should be of considerable help in wringing out higher performance from present designs. A porous nylon polymer developed by The Polymer Corp. will absorb 15-50% of oil by weight. The oil filled nylon parts will retain the oil under extreme conditions of pressure and temperature. Approximately 20% of the oil is retained after centrifuging at 15,000 G's. The nylon components can be formed by powder metallurgy techniques using specially processed nylon powders. Frictional coefficient of the oil-filled parts can be as low as 0.01 over extended periods of operation. The nylon parts can be used at PV's (pressure x velocity) of 40-70,000, or more than ten times those possible with ordinary nylon. It has been reported that microporous nylon retainers impregnated with 20-25% of instrument oil have operated under 800 G's in gyro ball bearings for inertial guidance systems without weight shift or oil loss. The inherent resilience of the nylon matrix permits the use of zero clearance to interference fit parts. The oil does not bleed out of the micropores, (.01-10 microns even under pressure).

A new grade of self-wicking lubricant for bearings operating in extreme conditions has been developed by the Permawick Company. The key to this lubricant is a new additive formulated specifically for bearing use. This new formulation has a pour point of −40C and shows essentially constant lubricity up to 200F. In addition to improving the operating characteristics of babbitt and sintered bronze bearings, it has proven to be effective in quieting noisy bearings.

A superdense ceramic has been produced by Gulton Industries, Inc. A radically new process reduces voids by 80% over presently available ferroelectric ceramics. The elimination of voids results in significantly higher piezoelectric sensitivity, higher dielectric constant and lower dielectric and acoustic losses with a 100% improvement in temperature stability. The new process also produces a ceramic having a highly uniform grain size with a corresponding improvement in the consistency of electromechanical properties. Larger one-piece ceramic units should be possible using this technique. One-piece transducer discs as large as 20 inches in diameter can be made. The basic operation of the process is the firing of the ceramic body under pressure from three axial directions to supply a net compacting force. Densities greater than 8.0 have been attained, compared with 7.5 for lead zinconate-titanite.

A new insulating tape from Continental Diamond Fibre Corp. has a specially designed cross-section to permit neat, tube-like tape wraps. The unique conforming quality results from using a base-to-base double triangular, or rhomboid cross-section. Thickness of the final tape layer is governed by the thickness of the tape at its apex. Tapes produce a smoooth external surface when the overlapping halves are matched, guided by a colored center line. The tape is made of silicone rubber with a polyester film interleaf.

Materials with low background levels of natural radioactivity have become a serious problem for electronic equipment precise enough to measure extremely low levels of radioactivity. Important research problems in geochronology, biology, meteorology and archeology depend upon electronic instrumentation with an extremely low level of radioactive contaminants. A new type of glass with only 6% of the radioactivity background of comparable glasses has been developed by the Corning Glass Works for the Atomic Energy Commission. The glass will be used for photomultiplier components and can be sealed readily to Dumet, Sylvania #4 and similar alloys.

Molybdenum Disulfide

A solid film lubrication that has been used in critical military applications for many years has not previously found wide industrial acceptance because of prohibitive initial cost and the need for expensive surface pre-treatment. However, a new speciallly prepared formulation of molybdenum disulfide, called Poxylube, is easily applied by any of the usual methods of painting such as spraying, brushing, or dipping. The dried film provides permanent lubrication on all types of rotating and sliding bearing surfaces. Poxylube produces outstanding lubricity, and formerly unobtained adhesion, to metals with no more surface preparation than simple degreasing. This amazing property enables industrial users to adapt this unusual lubricating system to existing products without major production modification. Poly Chem, Indianapolis, Indiana.

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Printed Circuit Base Material

A High-strength, peel-back resisting material, called Enrad II, has been developed for printed circuit boards. When the boards are laminated from Enrad II and fiberglas cloth, the result is a thin yet strong base material having outstanding temperature, moisture, and dielectric strength characteristics for VHF and UHF applications. When laminated with copper printed circuit boards made from Enrad II withstand a 20-second solder-dip test as well as a 5 to 9 pound peel-back test. The high strength of Enrad II boards permits them to be made as thin as 0.010" and to bend in small diameters to fit tight space requirements without cracking or crazing. Enflo Corp., Maple Shade, N. J.

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Hi-Temp Glass Epoxy Laminate

New glass-base, epoxy, resin laminated plastic for use at both normal and elevated temperature meets specifications for NEMA grade G-11 and military grade MIL-P-18177B-Type GEB. A one-eighth inch thick sheet, the laminate, designated GEC-111, retains at least 68 percent of its flexural strength after one hour exposure of 50 percent strength retention. Ability to retain strength at elevated temperatures makes GEC-111 particularly suitable for use as the base material for copper-clad laminated plastics. Printed circuit boards made from these copper-clad laminates will not distort when placed in solder baths. Taylor Fibre Co., Norristown, Pa.

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STAFF COLUMNIST

Hyman Olken

LAWRENCE RADIATION LABORATORY
University of California
Livermore, California

The Art Of Originality

Working Principles

This is the second column in Part II of a series on the Art of Industrial Inventing. In the previous column we discussed barriers to originality and proposed to suggest a number of questions that constitute working principles for overcoming these barriers and stimulating originality in engineering. Here is working principle I.

WORKING PRINCIPLE I—SPECIAL RANGE OF VALUES

Is there a special range of parameter values, or is there a special range of some natural phenomenon or of some operating characteristic within which a unique action or effect takes place? Such a unique action or effect will very frequently provide an inventor with a key idea element for unlocking the door to an invention.

For example, suppose that a saturable reactor be placed in series with the resistance load in an alternating current circuit (Fig 1). A sinusoidal input voltage will then produce a voltage level, at each reversal of the sine wave (Fig 2). This flat spot means a time interval during which the voltage across the load is zero. It is a special range in the voltage-time characteristic of the load in the ac circuit within which a unique effect takes place. Consequently, if a switch across the load in this circuit is opened and closed during this interval there will be no voltage, hence no sparking.

This unique effect provides the key to the following invention. Suppose we have a switch in the circuit operated during this zero-voltage interval so as to reverse the connections from the ac line to the load (Fig 3). This would in effect be a synchronous mechanical rectifier with zero voltage across the synchronous switch during its opening and closing. Such a mechanical rectifier would be exceptionally free from arcing and would have practically zero minimum (internal) voltage drop. Hence, despite all the advances in electronic and solid state rectifiers, this synchronous mechanical rectifier finds wide use in those areas of industry (particularly electroplating) where huge currents must be provided with practically complete freedom from arcing and from losses due to internal voltage drop. (For the saturable reactor action shown in Fig 2, see *Magnetic Amplifiers*, by H. F. Storm, John Wiley & Sons, pages 68 and 69. For the synchronous rectifier action shown in Fig 3 see Special Issue on Mechanical Rectifiers, *Brown-Boveri Review*, Dec. 1950.)

To appreciate how powerful a tool for stimulating originality in industrial invention this "working principle" can be, let us consider an exceptional case which led to a chain of original inventions, each resulting from the application of the same special range of one particular operating characteristic—the downward slope interval (negative resistance effect) of a current-voltage curve.

In the early days of radio there was need for powerful transmitters, but the conventional rotary, mechanical alternating current generator could not provide the frequency and power outputs desired. Some original solution to the problem was needed. The negative slope of the current-voltage curve of an electric arc was then known. Duddell connected a tuned circuit to it and thus produced a high frequency circuit with an inherent negative resistance characteristic—in other words, a generator of oscillations at the frequency of the tuned circuit. Poulsen (by enclosing the arc in a gas) made this generator capable of great power output at high (radio) frequencies and thus solved the high power transmitter problem. (See *Pioneers of Wireless*, E. Hawkes, Methuen & Co., London, 1927, pp. 291-292.)

Later, when vacuum tubes were first developed, Hull of G. E. noted that, for a special range of grid and plate voltages (grid voltage more positive than plate voltage) the plate-current curve of a triode first rose up normally, but then dipped downward. He recognized this as the negative resistance effect, coupled a tuned circuit to the tube operating in this region, and thus produced an electronic oscillator called the dynatron oscillator. (See Hull, A. W.,

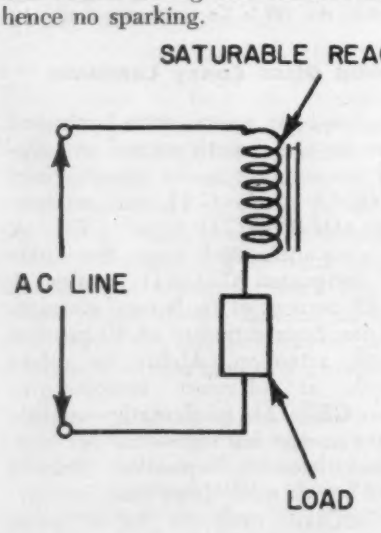

Fig 1

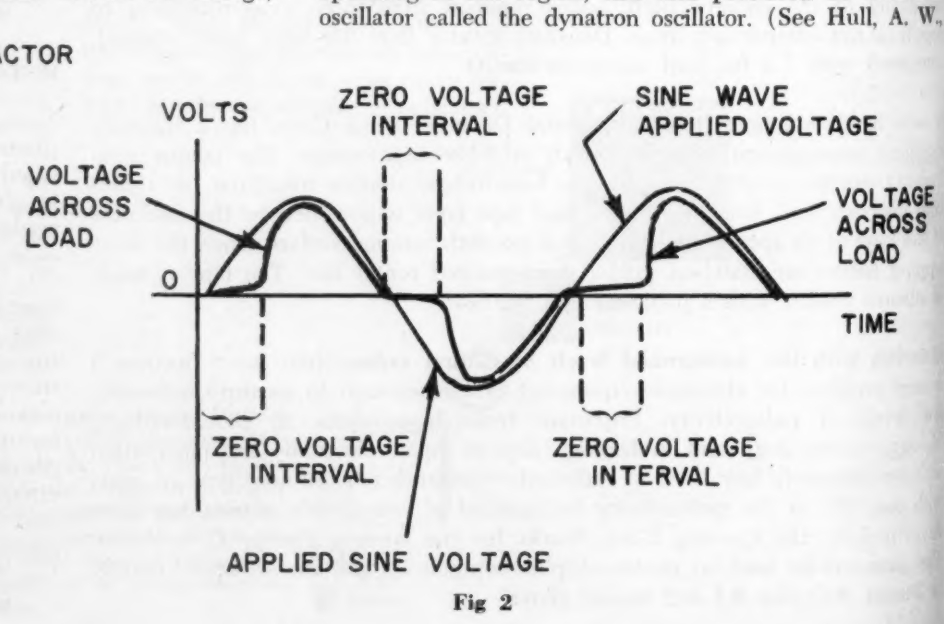

Fig 2

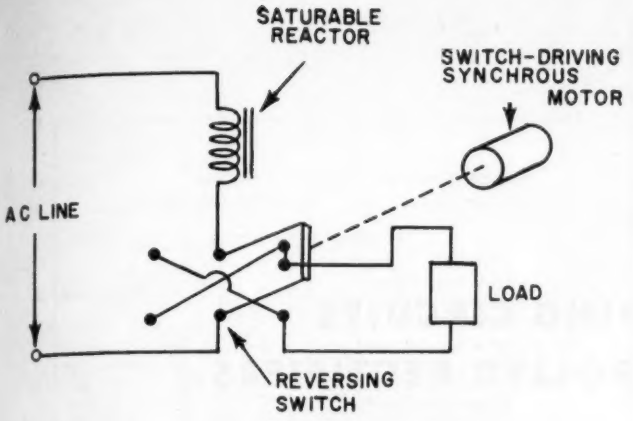

Fig 3

"Description of the Dynatron", *Proceedings of the Institute of Radio Engineers*, Vol. 6, No. 5, Feb. 1918.)

Still later, when multi-element tubes were developed, some radio engineers noticed that for a special range of voltages on the tube elements, the current-voltage curve for one of the tube elements also dipped downward—that is, it developed a negative slope—thereby indicating the presence of a negative resistance effect. They placed a tuned circuit in the lead of this tube element and thereby achieved a new high frequency oscillation generator—one which provided characteristics not found in the previous dynatron invention or in the conventional feed-back type of vacuum tube oscillator. (See "Negative Resistance and Devices for Obtaining It". E. W. Harold, *Proceedings of Institute of Radio Engineers*, Vol. 23, Oct. 1935, pages 1201 to 1221.)

Lately, Esaki of Japan observed that, for a particular range of design parameters, the p-n diode has a current-voltage curve with a very distinct downward slope, hence a negative resistance region. (L. Esaki, Letter to Editor in *Physical Review*, Vol. 109, Jan. 1958, p. 603.) Immediately a host of original inventions followed, not only for oscillators but also for amplifiers and other functional circuits, all based on this negative resistance characteristic. (See "The Tunnel Diode—Circuits and Applications", I. A. Lesk, N. Holynyak, Jr., and U. S. Davidsohn. *Electronics*, Nov. 27, 1959, pp. 60-64.)

To indicate how directly this working principle may lead to an original invention, consider the discovery of the fact that Pyrex glass is impermeable to all gases except one—helium. In this narrow special range—the "one-gas" (helium) gap—helium diffuses through "about a thousand times more readily than hydrogen." Here application of the unique effect is practically obvious—you use it to separate (extract) helium from raw material in which it occurs—natural gas.

K. B. McAfee of the Bell Telephone Laboratories who discovered this fact conceived the idea of putting natural gas under pressure in a chamber packed with thin-walled (Pyrex) glass tubing; the helium would pass through the walls into the tubing and thus be separated from other gases such as hydrogen and methane. The idea worked; the helium collected in the tubing is practically pure at the first pass. (See "Separating Helium", *Scientific American*, July 1958, p. 52.)

It is worth noting, from this example, the high degree of novelty and the great value of the invention that this "working principle" led to. The present method of obtaining helium from natural gas in the U. S. is low-temperature distillation, which is feasible only for gas containing at least one percent helium; the helium in less rich natural gas is being lost at the rate of ten million cubic feet per day. Studies at Bell indicate that the new process could salvage this helium. • • •

Next month—Working Principle II

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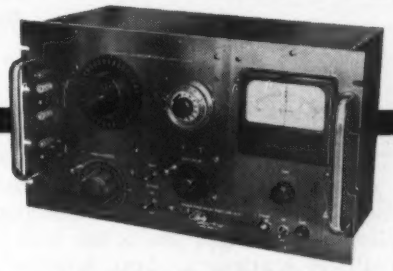

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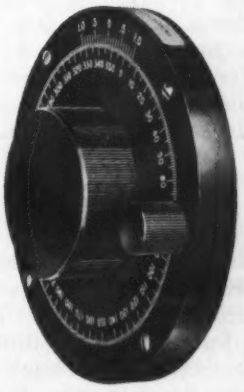

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DESIGN TIME SAVER

SURVEY OF FIRING CIRCUITS FOR SILICON CONTROLLED RECTIFIERS

By T. P. Sylvan, *Application Engineer*

Semiconductor Prods. Dept., General Electric Co., Syracuse, N.Y.

In our Components Digest on audio frequency power amplifiers, we predicted that the future of these devices lies in the growth of silicon controlled rectifiers. At present, the greatest drawback to the use of the SCR in discontinuous amplifiers is the high cost. If it follows the same path of the transistor, as it seems to be doing, its cost will continue to drop. Another drawback is that there are very few, if any, commercial SCR amplifiers on the market; thus the designer is obliged to build his own.

One of the basic problems in working with SCR's is the choice and proper design of firing circuits. This article which describes considerations involved in the design and selection of SCR firing circuits is based on Chapter 4 of General Electric's Controlled Rectifier Manual. The Chapter has been rewritten to include the applications of tunnel diodes.

The silicon controlled rectifier is a three terminal semiconductor device analogous to the gas thyratron. In the absence of a current into its control electrode or gate, the SCR will block voltages of either polarity between its anode and cathode terminals. When a positive voltage is applied to the anode with respect to the cathode, a firing signal consisting of a positive current into the gate will cause the SCR to switch from a high voltage, high impedance state to a low voltage, low impedance state. In the conducting state, the voltage across the SCR is of the order of 1 volt and the current in the anode-cathode circuit is limited only by the supply voltage and the load impedance. Once fired, the SCR will remain in the conducting state until the anode current drops to a low value.

GATE FIRING CHARACTERISTICS

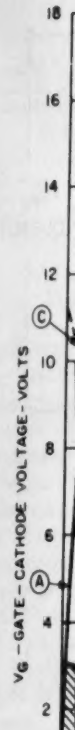
Gate input characteristics and firing characteristics of an SCR are presented on a single graph in Fig 1. From this figure it can be seen that the gate current requirements for firing decrease substantially as the junction temperature increases. Although not specifically portrayed in this figure, the gate current requirements also decrease slightly as the anode to cathode voltage is increased. Because of the temperature and anode effects on the control characteristic, it is desirable to fire SCR's with a steep wavefront of gate current whenever precise timing or phase control is required. For strictly on-off control, however, adjustment of gate current magnitude rather than timing is satisfactory, provided ample current is furnished for positive firing.

To prevent damaging the SCR, several limitations must be imposed on the gate signal. For the SCR of Fig 1, the peak positive voltage between the gate and cathode should not exceed 10 volts and the peak negative voltage between the gate and cathode should not exceed 5 volts. Peak forward gate current should be limited to 2 amps. Peak allowable gate power dissipation is 5 watts and the average gate power dissipation is 0.5 watts.

For reliable firing under all temperature conditions, the gate signal source should be designed to produce voltages and currents in excess of the values indicated by the shaded area in Fig 1 without exceeding the maximum limitations specified above. To assist in constructing gate signal load lines, the maximum allowable power dissipation curves for various duty cycles of gate signal have been plotted in Fig 1. For positive firing of all cells within the entire temperature range without exceeding the power limitations, load lines should be chosen so that they remain above and to the right of the shaded area and also remain below and to the left of the maximum allowable power dissipation curve that applies for the particular duty cycle being used. These maximum power dissipation curves assume that negligible gate dissipation occurs during the interval that negative voltage is applied to the gate. For example, if gate signal duration is one-quarter of the cycle, the duty cycle is 25%.

Fig 1 also indicates the gate voltage level below which no SCR will fire. At 125 C junction temperature, this value is 0.25 volt and at −65 C it is 0.75 volt. A linear variation occurs between these two temperature limits. This limit is important when designing a firing circuit which has a standby leakage current when no firing signal is present. Examples of this are saturable reactors and unijunction transistor firing circuits. To prevent misfiring under these circumstances, a resistor should be connected across the output of the firing circuit. Its value of resistance in ohms should not exceed 0.25 volt divided by the maximum standby current in amps.

Any negative voltage applied to the gate with respect to the cathode should not be allowed to exceed the reverse voltage rating of the gate. If there is a possibility that the reverse gate voltage rating might be exceeded, a diode should be connected either in series with the gate to limit the reverse gate current or from cathode to anode to



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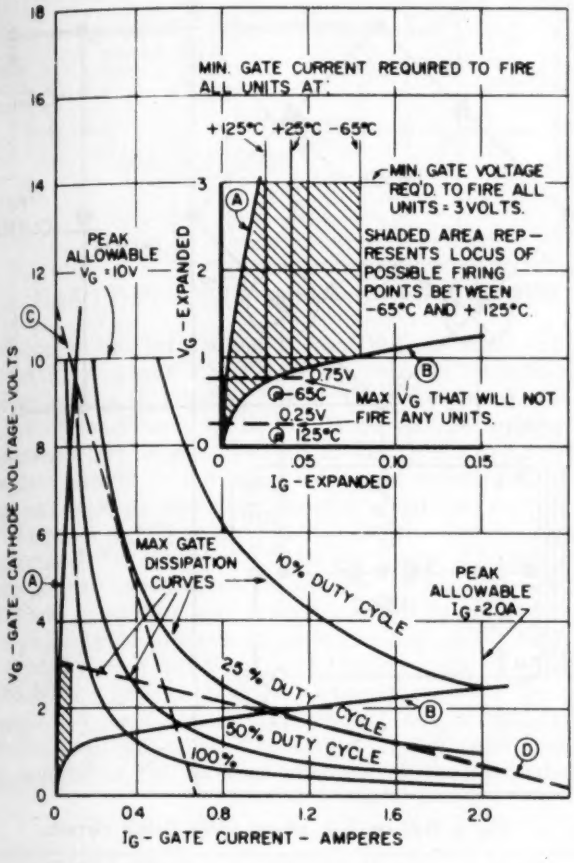
MIN. GATE CURRENT REQUIRED TO FIRE ALL UNITS AT:
+125°C +25°C -65°C
MIN. GATE VOLTAGE REQ'D. TO FIRE ALL UNITS = 3 VOLTS.
SHADED AREA REPRESENTS LOCUS OF POSSIBLE FIRING POINTS BETWEEN -65°C AND + 125°C.
PEAK ALLOWABLE V_G = 10V
V_G - EXPANDED
0.75V
-65C
0.25V
125°C
MAX V_G THAT WILL NOT FIRE ANY UNITS.
I_G - EXPANDED
MAX GATE DISSIPATION CURVES
10% DUTY CYCLE
PEAK ALLOWABLE I_G = 2.0A
25% DUTY CYCLE
50% DUTY CYCLE
100%
V_G - GATE - CATHODE VOLTAGE - VOLTS
I_G - GATE CURRENT - AMPERES

Fig 1 Gate and firing characteristics for a silicon controlled rectifier. This graph indicates the range of gate currents and voltages required to fire a typical medium current SCR. It also indicates the limit values of the voltage-current characteristic between gate and cathode (curves A and B). Dashed lines C and D illustrate the maximum limits of load lines at 25% duty cycle. For load line C, the peak open circuit voltage of the gate source is 11.6 volts and its short circuit current is 680 ma. For load line D, the values of open circuit voltage and short circuit current are 3.1 volts and 2.6 amps.

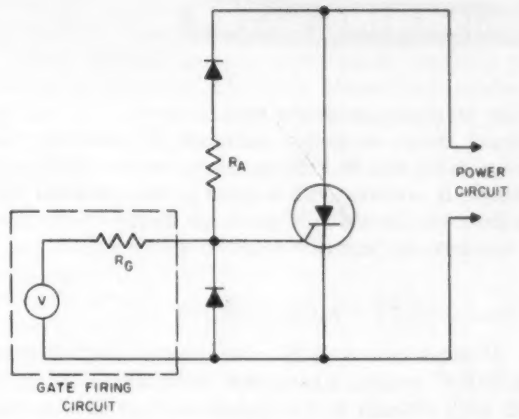

Fig. 2 Gate clamping circuit for negative anode voltages.

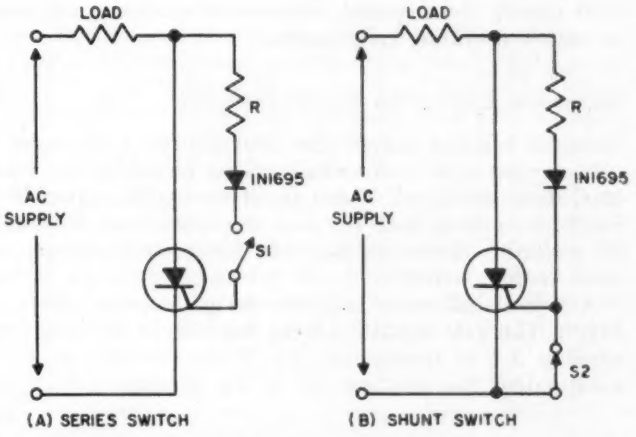

Fig 3 Half-wave ac firing circuits. Resistor R limits the peak gate current before firing occurs. The diode in the gate circuit is provided to prevent inverse voltage from being applied between cathode and gate during the reverse part of the cycle. If desired, the diode can be connected between gate and cathode rather than in series with R. Conduction is initiated by closing contact S1 in (A) or by opening contact S2 in (B). Interruption of load current occurs within one-half cycle after opening S1 or closing S2.

clamp the reverse gate voltage.

The presence of positive voltage on the gate when inverse voltage is applied to the anode increases reverse leakage current through the device substantially. This increased leakage current is roughly proportional to gate current and is due to transistor action in the SCR. Since this increased reverse leakage current causes excessive junction heating which can result in thermal runaway, it is recommended that gate voltage be limited to values below 0.25 volt during the inverse part of the cycle. Exception to this limitation can be taken if the gate signal is a pulse.

When a gate signal in excess of this minimum limit is encountered during the inverse cycle, a clamping circuit of the type shown in Fig 2 is recommended. Resistor R_A and a diode are connected from gate to anode to attenuate positive gate signals whenever the anode is negative. The required value of R_A depends on the voltage and impedance of the firing circuit and should be specified by the SCR manufacturer.

PULSE FIRING CHARACTERISTICS

The maximum gate signal necessary for firing the typical medium current SCR under the most adverse conditions (−65 C junction temperature) is 80 ma. at 3 volts. This requirement assumes either a dc level of this magnitude or a pulse of this magnitude with duration of at least 6 μsec. For pulses shorter than 6 μsec., the pulse amplitude necessary for firing varies inversely with the pulse duration. Thus, a 3 μsec. pulse should be at least 80 x 6/3 or 160 ma. in amplitude. Firing may occur with gate current pulses as narrow as 0.3 μsec. However, if the device is to remain in conduction, the circuit must allow anode current to build up at a sufficiently fast rate to reach a value in excess of the holding current I_H before the end of the gate pulse.

AC AND DC FIRING CIRCUITS

For simple on-off switching of SCR's in dc circuits, a continuous dc gate signal is satisfactory provided that the gate power dissipation does not exceed 0.5 watt. With dc circuits, separate means must be provided for turning off the SCR. With ac circuits, a continuous dc gate signal can also be used provided that clamping circuitry previously described is used to prevent thermal runaway dur-

ing the inverse part of the power cycle.

Fig. 3 shows a simple method of obtaining gate current for firing the SCR from the main ac supply whenever the anode is positive with respect to the cathode. When the SCR fires, the anode voltage drops to the conduction value and the gate current decreases to a low value.

AC PHASE SHIFT FIRING CIRCUITS

Fig. 4 illustrates a full-wave phase controlled rectifier using a R-C or R-L phase shift network to delay the gate signal with respect to the anode voltage. Many variations of this type of phase shift circuit have been worked out for thyratrons and can be applied to SCR's if allowance is made for the firing current requirements of the SCR. Because of the frequency dependence of this type of phase shift circuit, the required values of L or C become lower at higher operating frequencies.

SATURABLE REACTOR FIRING CIRCUITS

Saturable reactors provide the desirable steep wavefront of gate current with a convenient means of control by a low level dc or ac signal. This type of control is adaptable to feedback systems and provides the additional advantage of multiple, electrically-isolated inputs and outputs for more complex circuits.

A typical half-wave magnetic firing circuit is shown in Fig. 5. The gate signal for firing the SCR is obtained from winding 3-4 of transformer T1. When the core of T2 is unsaturated, the winding 3-4 of T2 presents a high im-

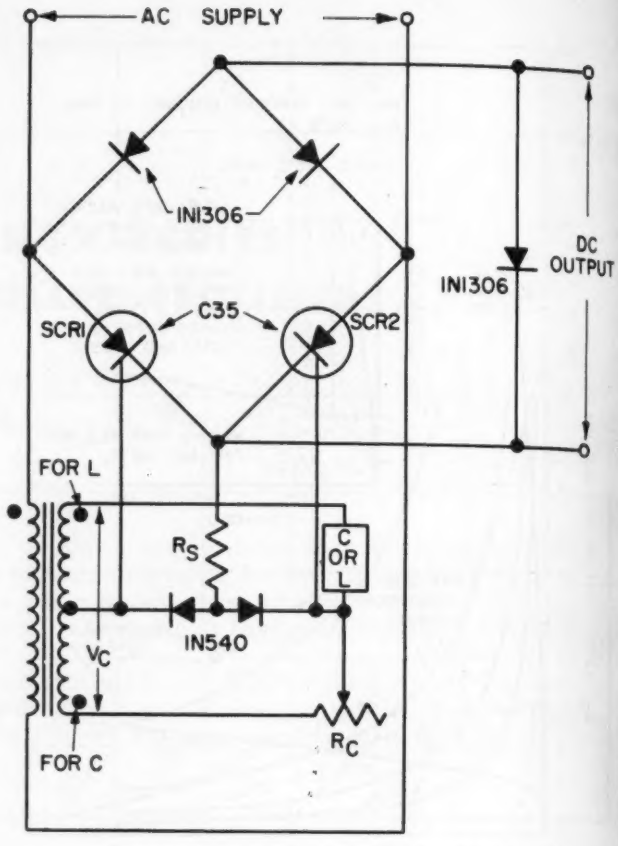

Fig 4 R-C or R-L phase shift firing circuit.

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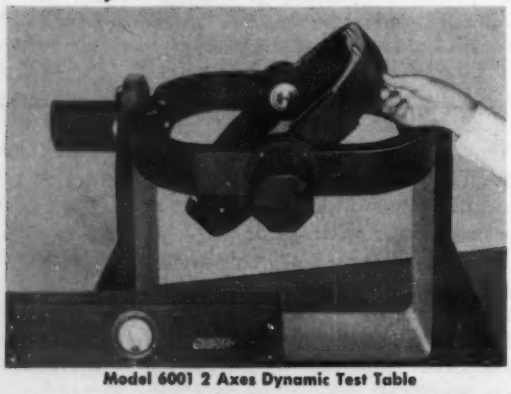

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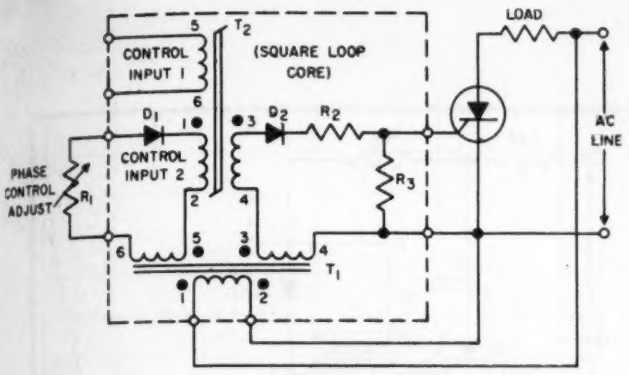

Fig 5 Typical half-wave magnetic firing circuit.

pedance to the gate signal so that only a small voltage is developed across R3. When the core of T2 saturates, the impedance of winding 3-4 of T2 decreases by several orders of magnitude so that a large voltage appears at the gate of the SCR causing it to fire. Resistor R2 limits the gate current to the rated value and resistor R3 limits the gate voltage produced by the magnetic current of winding 3-4 of T2 so that the SCR will not fire before the core of T2 saturates. Diode D2 serves the dual purpose of preventing a reverse voltage on the gate of the SCR and preventing any reverse current through winding 3-4 which would produce an undesired reset of the core T2.

Control signals can be applied to either input 1 or input 2 or both. Input 2 operates in the reset mode by controlling the reset voltage on winding 1-2 of T2 during the negative half cycle. The setting of the potentiometer R1 determines the amount of reset of the core during the negative half cycle which in turn determines the phase angle of the SCR conduction during the positive half cycle. Other control circuits such as a transistor amplifier stage can be used in place of R1. Since power is furnished by winding 5-6 of T1, no auxiliary power supply is needed. Input 1 operates in the magnetomotive force mode by controlling the current through the winding 5-6 and the core flux level which in turn determines the firing angle. The current for input 1 must be obtained from an external power supply or from a current generating type of transducer.

Additional output windings can be added to T2 for firing several SCR's in parallel. Also, additional control windings of the reset or mmf type can be added to T2. Full wave and multiple phase operation can be achieved by combining two or more half wave circuits.

Several companies can supply packaged magnetic firing circuits which are designed specifically for operation with SCR's. These companies can generally supply special designs where required and can also furnish literature on the application of magnetic firing circuits:
Avion Division, ACF Industries, 11 Park Place, Paramus, N.J.; Fairchild Engineering, 934 Hope Street, Springdale, Conn.; Control Division, Magnetics, Inc., Butler, Pa.; Magnetic Amplifiers, Inc., 632 Tinton Street, New York 55, N.Y.; Ovitron Corp., 37-05 48th Ave., L.I. City, N.Y.; Vectrol Engineering, Inc., P.O. Box 1089, Stamford, Conn.

Magnetic firing circuits designed for phase control applications, such as the one shown in Fig. 5, require the use of saturable cores that are large enough to allow the output winding to sustain the gate voltage signal for a full half cycle without saturating. For simple on-off control applications, the magnetic firing circuits of Fig. 6 permit

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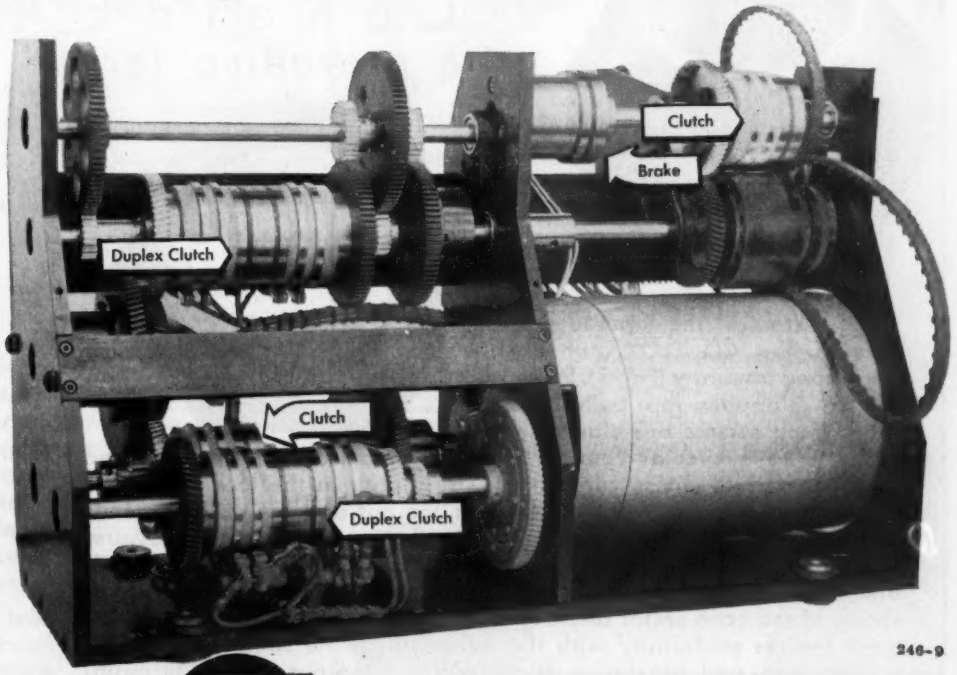

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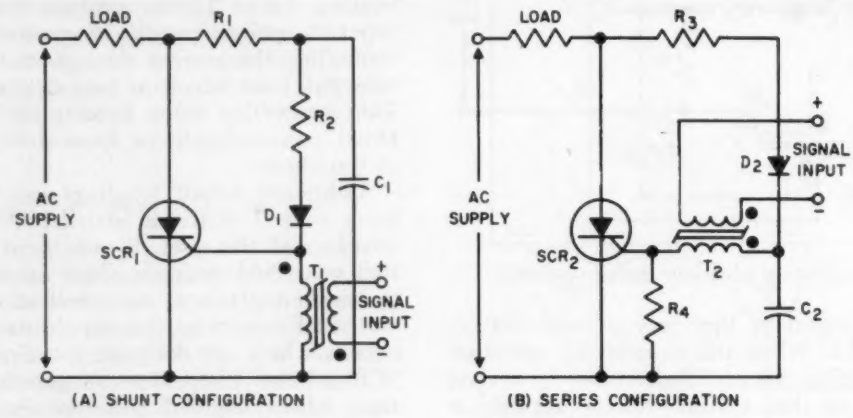

Fig. 6 Half-wave on-off magnetic firing circuits. (A) One winding of saturable transformer T1 is connected in shunt with the gate of SCR1. If T1 is unsaturated, the current through R1, R2 and D1 will flow into the gate of SCR1 during the first part of the positive half cycle and cause SCR1 to turn-on. If T1 is saturated, the current through R1, R2 and D1 will be diverted from the gate by the low impedance of the winding on T1. Also, when T1 is saturated, it can be reset and the SCR can be made to fire by a positive voltage on the signal input. Capacitor C1 provides filtering for the gate signal to prevent undesired firing due to fast transients on the ac supply. (B) One winding of saturable transformer T2 is connected in series with capacitor C2 and the gate of SCR2. If T2 is unsaturated, the current through R3 and D2 will charge C2 during the initial part of positive half cycle. T2 will saturate after a few degrees of the positive half cycle and permit rapid discharge of C2 into the gate of SCR2 thus causing it to fire. If T2 is initially saturated at the beginning of the positive half cycle, the winding of T2 will divert the current from C2 and prevent C2 from being charged. Resistor R4 prevents the voltage at the gate of SCR2, produced by the current through R3, from exceeding the minimum gate firing voltage. When T2 is saturated it can be reset and the SCR can be made to fire by a positive voltage at the signal input.

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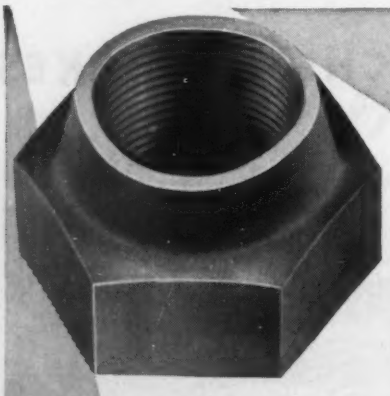

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Fig. 1

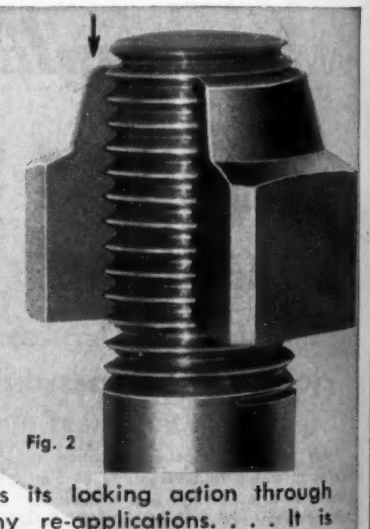

Fig. 2

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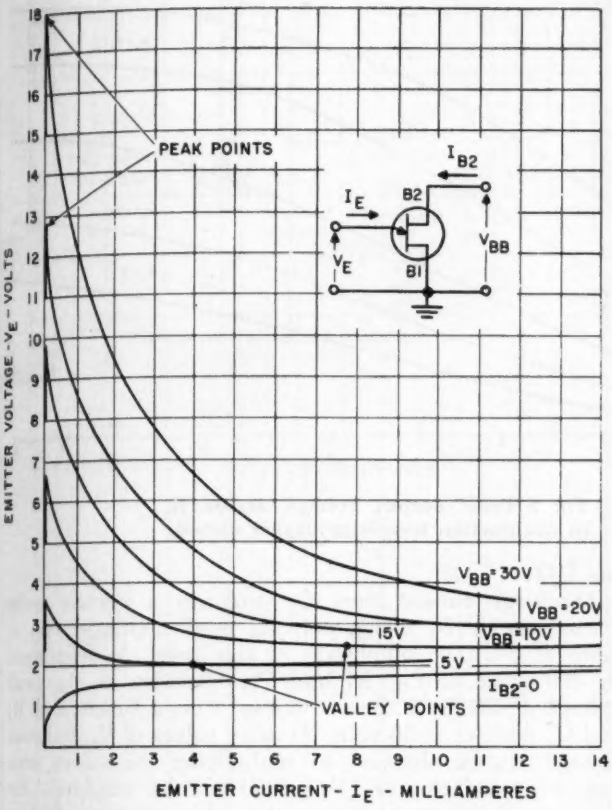

Fig 7 Unijunction transistor symbol and emitter input characteristics.

the use of smaller and less expensive cores since the output winding is not required to sustain the gate voltage signal for a full half cycle. In addition, these circuits have the advantage of not requiring the use of an auxiliary supply transformer.

The circuits of Fig 6 permit the SCR to perform the function of an ac contactor with an isolated dc control winding. Modifications of these circuits permit full wave operation with normally open, normally closed or latching operation.

UNIJUNCTION TRANSISTOR FIRING CIRCUITS

As an ideal device for use in SCR firing circuits, the silicon unijunction transistor (UJT) has the advantages of a stable firing voltage, a very low firing current, operation over a temperature range of −55 to +175 C, and a peak current rating of two amps. SCR firing circuits using the UJT are simple and compact with a low power consumption and a high effective power gain in phase control circuits.

The UJT has three terminals which are called the emitter (E), base-one (B1), and base-two (B2). Between B1 and B2 the unijunction has the characteristics of an ordinary resistance. This resistance is called the interbase resistance (R_{BB}) and at 25 C has values in the range from 4.7K to 9.1K. The interbase resistance increases linearly with temperature up to about 140 C.

Normal biasing conditions for the UJT are indicated in Fig 7. If the emitter voltage, V_E, is less than the emitter peak point voltage, V_P, the emitter will be reverse biased and only a small reverse leakage current, I_{EO}, will flow. When V_E is equal to V_P and the emitter current, I_E, is greater than the peak point current, I_P, the UJT will turn on. In the on condition, the resistance between the emitter

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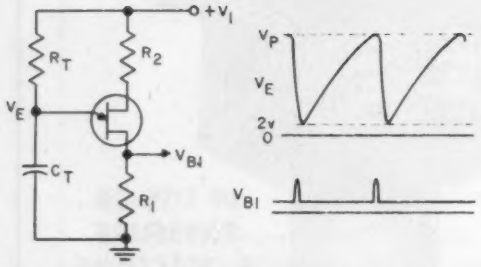


Fig 8 Basic unijunction transistor trigger circuit with typical waveforms.

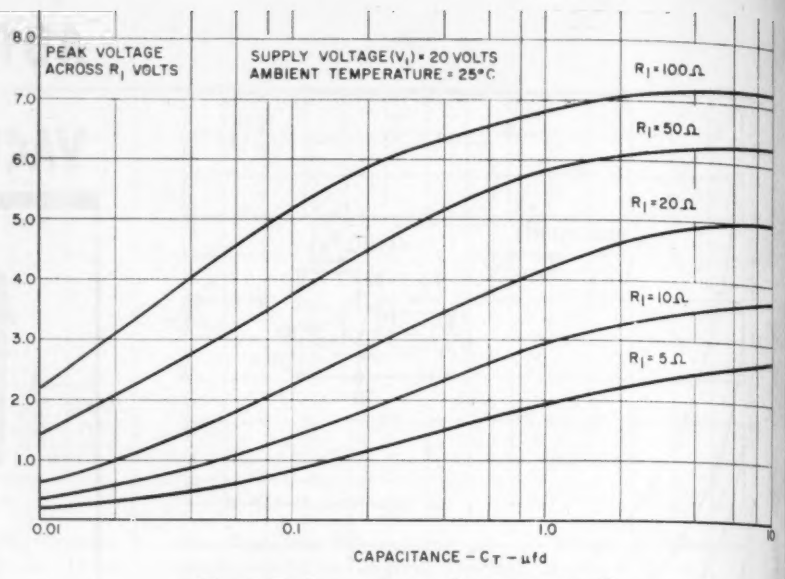


Fig 9 Peak output voltage across R_1 in unijunction transistor trigger circuit.

and base-one is very low and the emitter current will be limited only by the series resistance of the emitter to base-one circuit. When measured with pulse current over 30 milliamperes, the ac resistance between emitter and base-one lies in the range from 5 to 20 Ω.

Peak point voltage of the UJT varies in proportion to the interbase voltage, V_{BB}, according to the equation;

$$V_P = \eta V_{BB} + V_D \qquad (1)$$

Parameter η is called the intrinsic standoff ratio and is independent of bias conditions and temperature. The value of η lies between 0.51 and 0.75, according to the particular type of UJT. The voltage V_D is the equivalent emitter diode voltage which at 25 C is about 0.70 volts. V_D decreases with temperature with the temperature coefficient of about –2mv/°C. Most of the variation of the peak point voltage with temperature may be ascribed to the change in V_D. It is possible to compensate for this temperature change by means of a resistor in series with base-two as shown in Fig. 8.

Basic UJT trigger circuit used in applications with the SCR is a simple relaxation oscillator, shown in Fig. 8. In this circuit, the capacitor C_T is charged through R_T until the emitter voltage reaches V_P at which time the UJT turns on and discharges C_T through R_1. When the emitter voltage reaches a value of about 2 volts, the emitter ceases to conduct, the UJT turns off and the cycle is repeated. The period of oscillation, T, is fairly independent of the supply voltage and the temperature, and is given by:

$$T = 1/f \cong R_T C_T \ln (1/1-\eta) \qquad (2)$$

Design conditions on the UJT firing circuit are very broad. In general R_1 is limited to a value below 100 ohms although values up to 2 or 3 K are possible in some applications. Resistor R_T is limited to a value between 3K and 500K. The lower limit on R_T is set by the requirement that the load line formed by R_T and V_1 intersect the emitter characteristic curve of Fig. 7 to the left of the valley point, otherwise the UJT in Fig. 8 will not turn off. The upper limit on R_T is set by the requirement that the current flowing into the emitter at the peak point must be greater than the peak point current I_P for the UJT to turn on. Recommended range of supply voltage V_1 is from 10 volts to 40 volts and is determined on the low end by the acceptable values of signal amplitude and at the high end by the allowable power dissipation of the UJT.

Discharge current from C_T produces a positive pulse across resistor R_1 which may be used to trigger one or more SCR's. The amplitude of this pulse is determined by the value of C_T, R_1 and V_1. Variation of the peak voltage across R_1 is shown in Fig. 9 as a function of R_1 and C_T with $V_1 = 20$ volts. At other values of V_1, the peak voltage can be obtained by multiplying the values from Fig. 9 by a factor of $(V_1 - 6)/14$. Pulse amplitude decreases with increasing temperature, having a temperature coefficient between –0.15%/°C and –0.30%/°C. This is an advantage in SCR firing circuits since the triggering requirements of the SCR also decrease with increasing temperature.

If the basic trigger circuit is coupled by series resistors to the gates of the SCR's, the value of R_1 should be low enough to prevent the dc voltage at base-one from rising above 0.25 volts (the minimum firing voltage for the SCR's). Similarly, if parallel firing of two or more SCR's is used, the pulse amplitude across R_1 must be large enough to fire each of the SCR's assuming the worst conditions with regard to the required gate current and gate voltage.

If dc isolation is required between the trigger circuit and the SCR's, transformer coupling can be used. Generally small pulse transformers are adequate for this purpose. The optimum turns ratio is about 1:1 and the primary inductance should be 6 millihenries or more.

The UJT can be fired at any intermediate part of the cycle by reducing either the interbase voltage or the supply voltage V_1. This results in an equivalent decrease in V_P, in accordance with equation (1) and permits the UJT to fire if V_P drops below the instantaneous value of V_E. Thus the base two terminal or the main supply voltage can be used to synchronize the basic trigger circuit.

Two methods of achieving synchronization with the ac line are illustrated in Fig. 10. A full wave rectified signal obtained from a rectifier bridge or similar source is used to supply both power and synchronizing signal to the firing circuit. The zener diodes, D1 and D2, are used to clip and regulate the peaks of the ac.

TUNNEL DIODE FIRING CIRCUITS

Variation of the gate firing current and voltage with ambient temperature and from unit to unit, prevents the

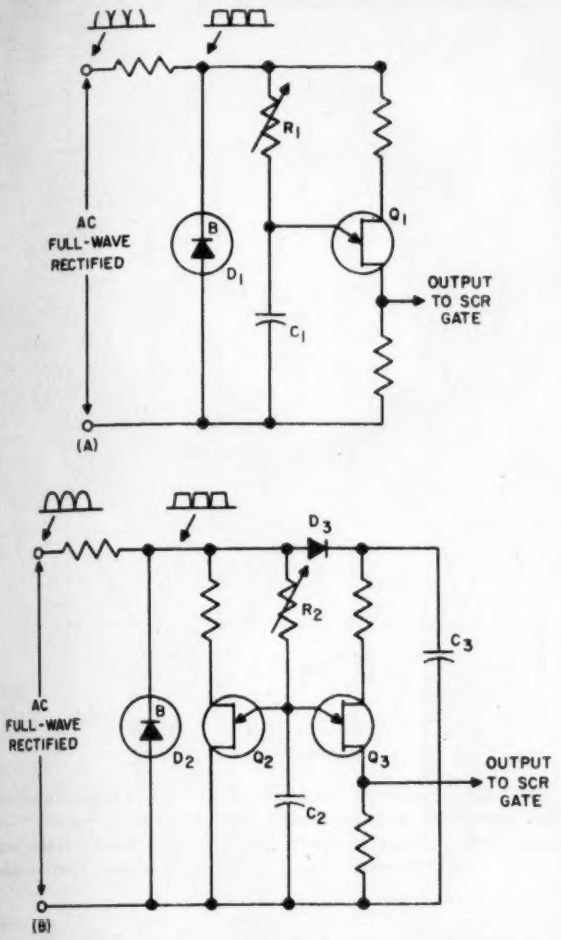
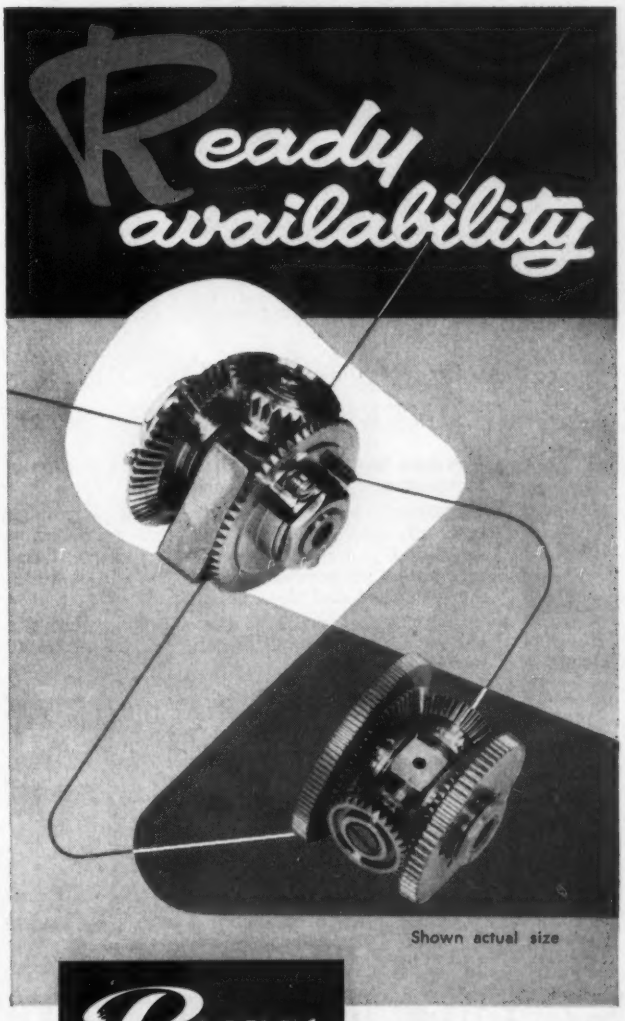


Fig 10 Circuits for synchronization to ac line. At the end of each half cycle, the voltage at base-two of Q1 and Q2 will drop to zero, causing Q1 and Q2 to fire. Capacitors are thus discharged at the beginning of each half cycle and the firing circuits are synchronized with the line. In (A), a pulse is produced at the output, at the end of each half cycle, which can cause the SCR to fire and produce a small current in the load. If this is undesirable, a second UJT can be used for discharging the capacitor at the end of the half cycle as shown in (B). Diode D3 and capacitor C3 are used to supply a constant dc voltage to Q3. The voltage across Q2 will drop to zero, each half cycle, causing C2 to be discharged through Q2. The UJT's should be chosen so that Q2 has a higher standoff ratio than Q3.

use of SCR's alone as precision voltage or current detectors. However, a tunnel diode used in conjunction with a SCR will result in a firing characteristic which is very uniform and stable with respect to temperature.

The tunnel diode is a two terminal negative conductance device which has the voltage-current characteristics shown in Fig. 11. As the current through the diode is increased from zero, the voltage across the diode will be low until the peak point is reached, at which time, the diode will switch to a higher voltage state. Diodes can be made with practically any desired value of peak point current, I_P, but the voltages are fixed and are determined only by the semiconductor material used. The two materials presently being used in the manufacture of tunnel diodes are germanium and gallium arsenide. As indicated in Fig. 11, gallium arsenide has approximately twice the output voltage of germanium.



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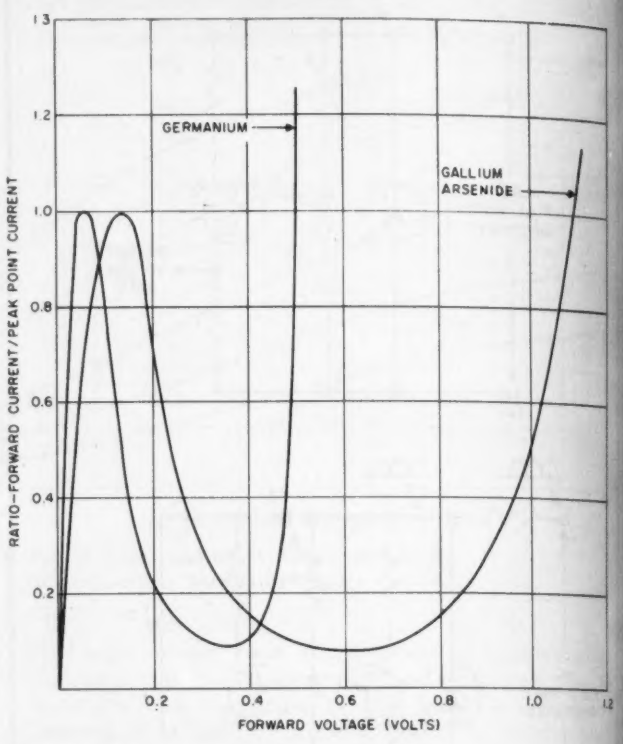


Fig 11 Voltage-current characteristics of germanium and gallium arsenide tunnel diodes presented in a paper, "Germanium and Silicon Tunnel Diodes," by Lesk, Holonyak, Davidsohn and Aarons, at the 1959 Wescon Convention.

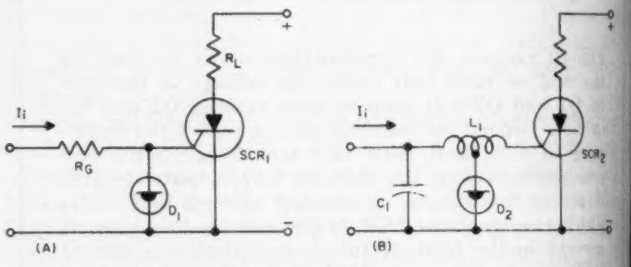
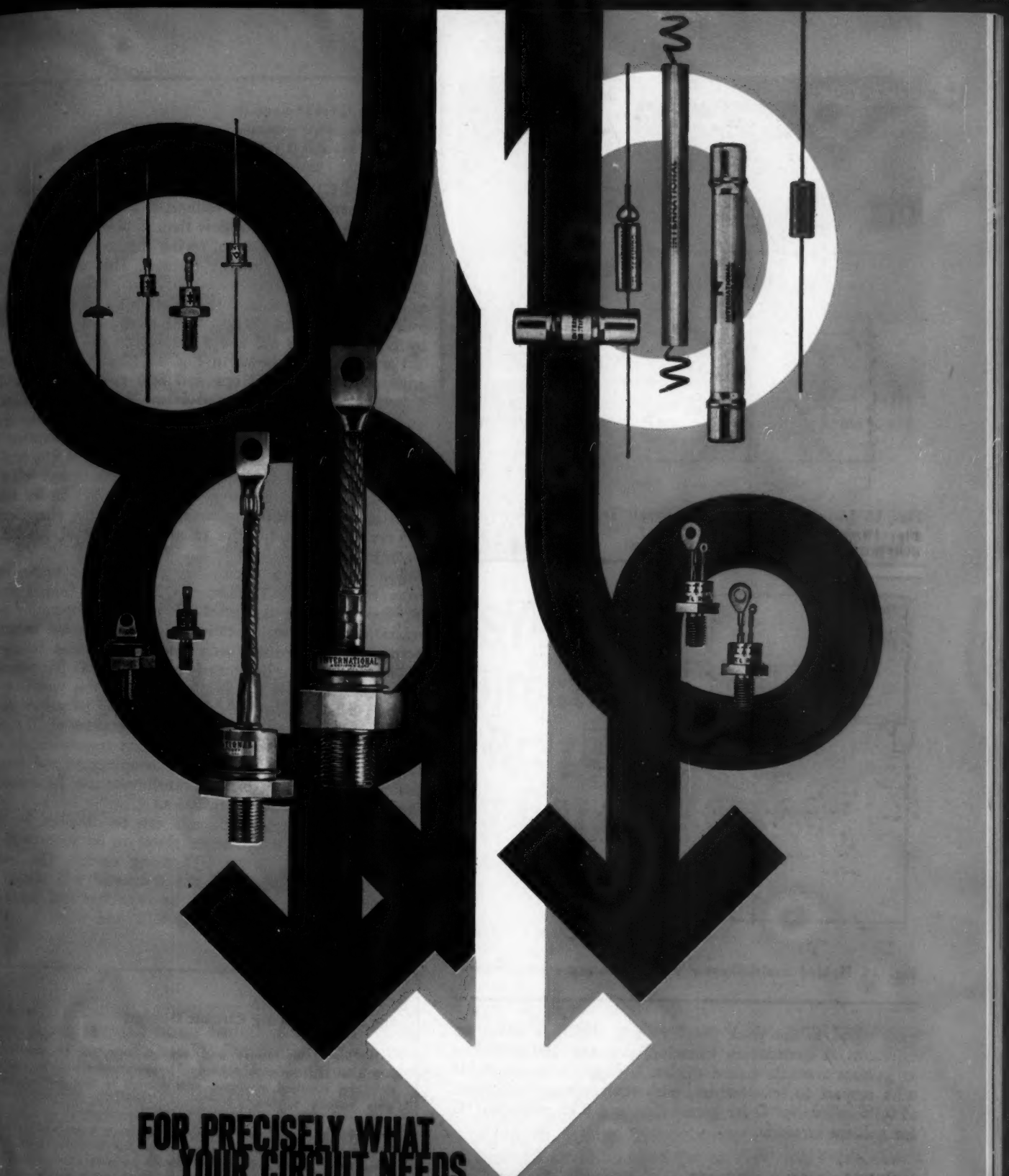


Fig 12 Tunnel diode firing circuits for SCR's.

If a gallium arsenide tunnel diode is connected between the gate and cathode of an SCR, Fig 12 (A), the gate voltage will remain low until the input current exceeds the peak point current I_P of the tunnel diode. The tunnel diode will then switch and the voltage at the gate will rise to approximately 1 volt. If gate firing voltage is less than 1 volt and gate firing current is less than I_P, the SCR will turn on. Note, in Fig 12 (A), that resistance R_G must be considerably larger than the negative resistance of the tunnel diode, otherwise the tunnel diode will not switch to its high voltage state.

If gate firing voltages are greater than 1 volt, two or more tunnel diodes with the same peak point current can be used in series or the circuit of Fig 12 (B) can be used. Here the voltage applied to the gate is higher than the voltage swing of the tunnel diode, due to the autotransformer action of L_1. Inductance of L_1 should be high enough to generate a gate pulse more than 6 μsec wide. Capacitor C_1 guarantees a low source impedance for I_i during the triggering interval.

Tunnel diode firing circuits are extremely useful in current limiting circuit breakers where it is desired to keep the voltage across the current monitoring resistor to an absolute minimum. Reliable firing can be obtained at vol-



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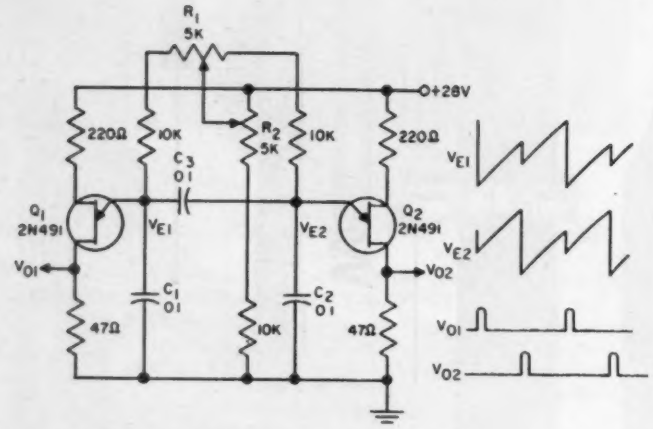


Fig. 13 Unijunction transistor circuit for generating alternate pulses.

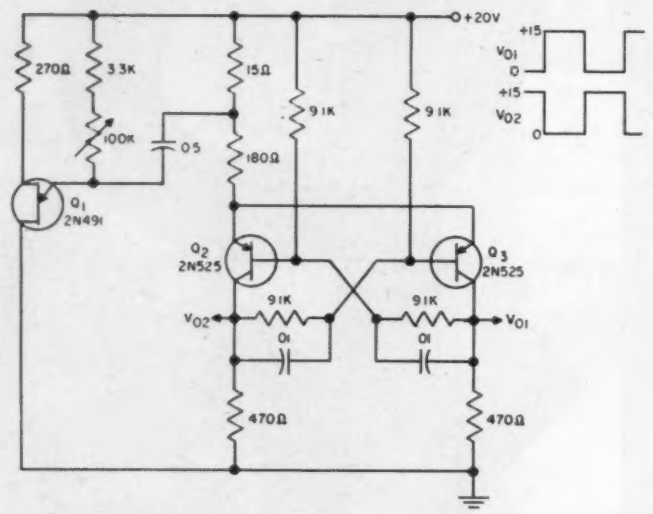


Fig. 14 Hybird multivibrator for generating square waves.

ages equal to the peak point voltage which is about 60 millivolts in germanium tunnel diodes and 160 millivolts in gallium arsenide tunnel diodes. Voltages are very stable with respect to temperature, with temperature coefficients of 0.08 millivolts/°C for germanium and 0.12 millivolts/°C for gallium arsenide.

INVERTER FIRING CIRCUITS

For triggering SCR parallel inverter circuits, a generator is desired which will produce trigger signals alternately at two outputs. The trigger signals can be either square waves or pulses depending on the circuit requirements. A pulse signal is generally preferable since it requires a minimum of power from the trigger circuit. A square wave signal is required for some types of parallel inverters operating with inductive loads.

Fig. 13 shows a simple UJT circuit which can be used for generation of alternate pulses. This circuit consists of two UJT relaxation oscillator circuits which are synchronized by the capacitor C3. Each time one UJT fires, a negative voltage step is coupled to the emitter of the opposite UJT through the capacitive voltage divider formed by C3 and C1 or C3 and C2. If this negative voltage step occurs when the emitter voltage is low, the delay in the firing of the UJT will be less than if the step occurs when the emitter voltage is high, owing to the non-linear charging characteristic of the capacitor. This effect produces the synchronization between the two oscillators. The frequency of oscillation and the relative spacing between the pulses from the two outputs are controlled independently by potentiometers R2 and R1 respectively.

For the circuit shown in Fig. 13, the frequency can be adjusted between 200 cps and 800 cps and the relative pulse spacing can be varied from 35% to 65%. Range of control of pulse spacing can be increased by reducing the size of C3 relative to C1 and C2. This size determines the initial timing of the pulses when the power is first applied. If C3 is the same size as C1 and C2, the circuit will start with the same timing sequence that it has under steady state conditions (50% pulse spacing). This characteristic is very important for the reliable starting of parallel inverters.

Fig. 14 shows a circuit for generating a square wave from two outputs. Transistors Q2 and Q3 form a simple flip-flop which is triggered by the UJT operating as a relaxation oscillator. Negative trigger pulses are generated across the 15 Ω resistor each time the UJT fires. Frequency of oscillation can be varied by the 100K potentiometer from approximately 20 cps to 600 cps; the waveform remains perfectly symmetrical over the full frequency range. The circuit will operate up to a temperature of 75 C with higher temperatures possible if silicon transistors are used for Q2 and Q3. If transformer coupling to the gates is desired, the primary of the transformer can be connected in place of the collector resistors.

Simple phase control circuits can be obtained by using a PNP or NPN transistor in shunt or in series with the emitter capacitor of the UJT firing circuit. The amount of current in the base of the transistor will control the effective charging current to the capacitor and hence will control the firing angle of the UJT and SCR. •••

CHECK LIST
for Proper Firing Circuit Design

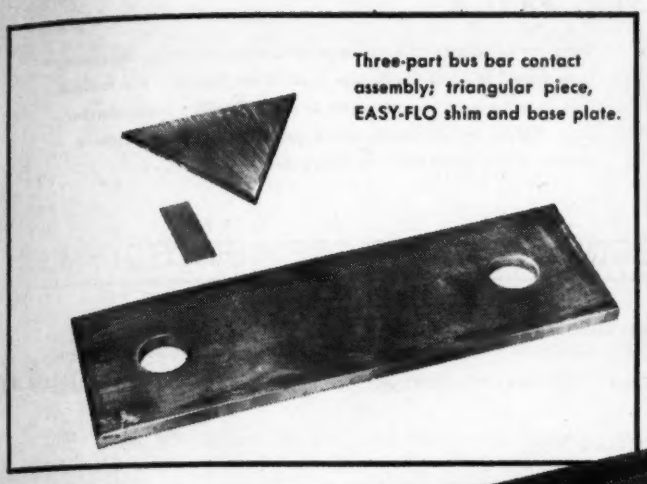
(1) The gate current and voltage supplied by the firing circuit at the minimum operating temperature should be greater than the specified maximum gate current to fire and maximum gate voltage to fire.

(2) For a pulse firing circuit, the minimum pulse width should be adequate to assure proper firing. For inductive loads, the pulse width of the firing circuit should be wide enough to allow the anode current to exceed the holding current before the end of the pulse.

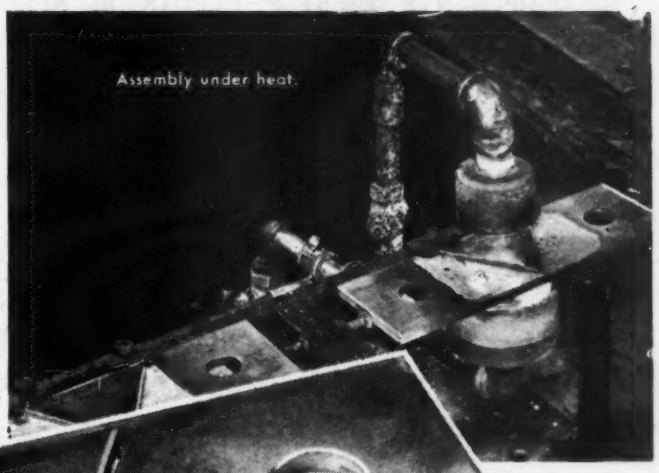
(3) The following gate ratings should not be exceeded under any conditions of operation:
- Maximum forward gate voltage.
- Maximum reverse gate voltage.
- Maximum forward gate current.
- Peak gate power.
- Average gate power.

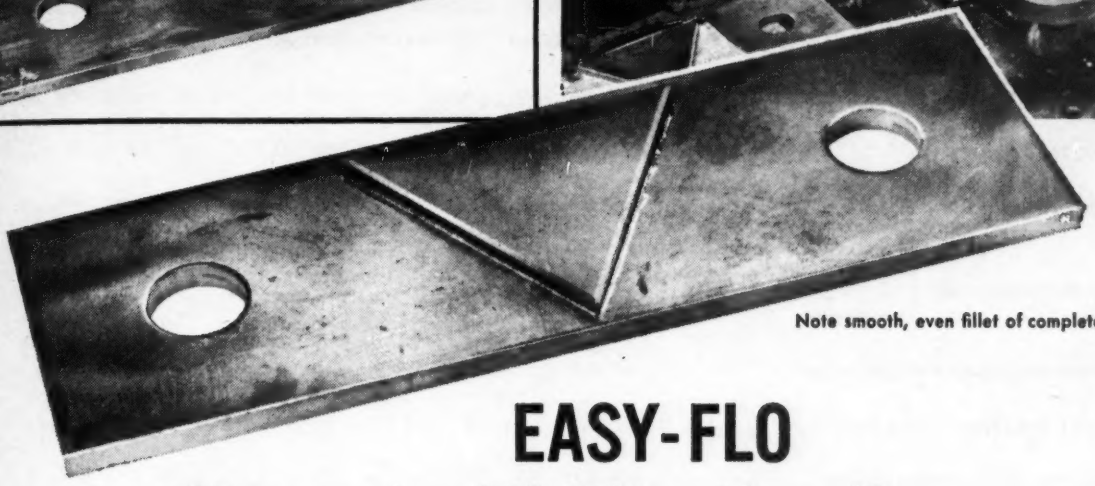
(4) A forward gate current should not be allowed to flow when the anode is negative with respect to the cathode.

(5) The gate voltage should not be allowed to exceed the minimum gate firing voltage under any conditions when firing is not desired.



Three-part bus bar contact assembly; triangular piece, EASY-FLO shim and base plate.





Note smooth, even fillet of completed assembly.

EASY-FLO "Moves in All Directions" to Braze Bus Bar Contact

Specialty Brazing Laboratory, Riverside, Connecticut, brazes, among other things, a bus bar contact for Rolock, Inc., Fairfield, Connecticut, makers of fabricated metal products. While a relatively simple assembly, it points up the remarkable *fluidity* of Handy & Harman Silver Brazing Alloys.

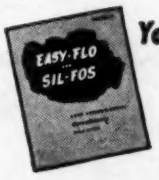
Both assembly components are copper. Base plate dimensions are ¼" x 8¾" x 2¾", and the ⅛" thick triangular piece is 3" on its base with 2⅞" sides.

After cleaning, the joint area of the base plate is HANDY-FLUXED and a shim of EASY-FLO 45 is placed on the base plate and the triangular piece set upon the shim. Heating by Selas gas-air burners is done on a 50-second cycle. Alloy cost is approximately four cents per assembly.

You'll notice, in the photo of the completed assembly, how smooth the alloy fillet is. The capillary action of EASY-FLO causes it to flow out in three directions, providing even joint penetration. This single fact (without going into the qualities of strength, conductivity, corrosion resistance, etc.) makes EASY-FLO a natural for electrical applications. Handy & Harman has, readily at hand, extensive data on the advantages of silver brazed joints for electrical applications. We are always ready and happy to discuss joining requirements and techniques with you. Your call or inquiry will bring complete and beneficial details.

FIRST, BULLETIN 20

This informative booklet will get you off to a good start on the values, techniques and economies of low-temperature silver brazing. A copy awaits your request.



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CIRCLE NO. 29 ON INQUIRY CARD

←CIRCLE NO. 54 ON INQUIRY CARD

COMPONENTS DIGEST 12-ELECTRICAL RESOLVERS, PART II

This digest is designed to give engineers the background information they need in specifying electrical resolvers. Part I appeared in the Feb. 1960 issue. This concluding part lists manufacturers' data on a variety of induction resolvers. The tabulation is only representative of the range of available types. The reader should contact manufacturers for additional information prior to final selection. No assumptions should be made where data on units are omitted. For example, data on some units are given only in uncompensated form, however, most of these models can be compensated to achieve performance similar to that given for competitive units.

SUMMARY OF INDUCTION RESOLVER CHARACTERISTICS

1. CO. NAME AND ADDRESS		American Electronics, Inc., Instr. Div. Culver City, California					
2. MODEL NUMBER		1R8W4-602	1R11WA-127	1R11N4-137	1R15W4-425	1R8N4-601	1R23H8-500
3. FREQUENCY (cps)		400	400	400	400	400	60
4. INPUT VOLTAGE (volts)		26	26	60	60	26	25
5. LOW CORNER FREQUENCY (cps)		210	70	50	60	105	5
6. PEAKING FREQUENCY (cps)	uncompensated	190k	50k	67k	80k	190k	30k
	compensated	---	70k	---	---	---	---
7. MAX. PERPENDICULARITY OF AXIS (minutes)		± 5	± 5	± 5	± 5	± 5	± 3
8. TOTAL NULL VOLTAGE (mv/volt input)		1	1	1	1	1	1
9. MAXIMUM FUNCTIONAL ERROR (percent)		0.1	0.1	0.1	0.1	0.1	0.05
10. TRANSFORMATION RATIO	primary to secondary	0.87 ± 0.02	0.975 ± 0.02	0.980 ± 0.02	0.980 ± .01	0.47 ± 0.02	0.989 ± 0.1
	compensator primary to secondary	0.99 ± 0.02	0.990 ± 0.01	---	1.000 ± 0.00025	---	---
11. TIME PHASE SHIFT (degrees)	primary to secondary	26	8.5 ± 1	7 ± 1	8.0 ± 1	14	4.6 ± 0.6
	compensator primary to secondary	0	0 ± 0.15	---	0	---	---
12. FRAME SIZE		8	11	11	15	8	23

1. CO. NAME AND ADDRESS		Diehl Mfg. Co. Somerville, New Jersey					Kearfott Div., Gen. Precision, Inc. Little Falls, New Jersey	
2. MODEL NUMBER		B11R8-2	B11R9-3	B11R7-2	B15R1-1	B11R9-1	T980-51	R980-01	425506-1
3. FREQUENCY (cps)		400	400	400	400	400	400	400	400
4. INPUT VOLTAGE (volts)		10	10	10	26	10	26	60	25
5. LOW CORNER FREQUENCY (cps)		45	70	80	---	70	---	---	---
6. PEAKING FREQUENCY (cps)	uncompensated	100k	100k	100k	---	55k	---	---	---
	compensated	---	---	---	---	---	---	---	---
7. MAX. PERPENDICULARITY OF AXIS (minutes)		± 4	± 4	± 4	± 5	± 4	---	---	---
8. TOTAL NULL VOLTAGE (mv/volt input)		1	1.5	1	1	1.5	0.58	0.42	0.6
9. MAXIMUM FUNCTIONAL ERROR (percent)		± 0.03	± 0.03	± 0.03	± 0.1	± 0.03	0.1	0.2	0.00015
10. TRANSFORMATION RATIO	primary to secondary	0.975	0.965	0.975	0.98 ± 0.01	0.970	0.980 ± 0.01	0.980 ± 0.020	0.980 ± 0.019
	compensator primary to secondary	---	0.975	---	0.99 ± 0.005	0.960	0.950 ± 0.05	0.985 ± 0.010	0.985 ± 0.009
11. TIME PHASE SHIFT (degrees)	primary to secondary	6	9	7	---	11	8.5	8.5 ± 2	2
	compensator primary to secondary	---	8.5	---	---	10.5	---	---	---
12. FRAME SIZE		11	11	11	15	11	15	11	25

SUMMARY OF INDUCTION RESOLVER CHARACTERISTICS (CONTINUED)

1.	Bendix Corp., Eclipse-Pioneer Div. Teterboro, New Jersey					Clifton Precision Products Co., Inc. Clifton Heights, Pennsylvania					
2.	AY540-5	AY543-38A1	AY229G-B63-B	AY221S-51B	AY620-18A1	CSC-8-A-1	CSC-10-AS-1	CS-15-D-1	CZC-15-JS-3	CS-11-B-2	BSC-15-DS-3
3.	400	400	400	400	400	400	400	400	400	400	400
4.	26	26	50	26	26	26	26	26	55	22	26
5.	---	---	---	---	---	---	---	---	---	---	---
6.	---	---	---	---	---	---	---	---	---	---	---
	---	---	---	---	---	---	---	---	---	---	---
7.	---	---	---	± 3	± 10	---	---	---	± 5	---	± 5
8.	---	1.9	1	---	1.9	1.15	1	1	1.3	1.4	1
9.	0.5	0.5	0.1	0.018	0.28	0.2	0.21	0.14	0.1	0.17	0.1
10.	---	---	0.825	1.81 ± 0.05	0.943	0.415	0.435	0.454	0.987	1.02	0.954
	---	---	---	---	---	---	---	---	---	---	---
11.	12	11	6	6.3 ± 1	9	20	18	8.5	4	5	4
	---	---	---	---	---	---	---	---	---	---	---
12.	10	10	15	15	11	8	10	15	15	11	15

1.			Muirhead Instruments, Inc. New York, New York						Norden Div., United Aircraft Corp., Ketay Dept. Commack, Long Island, N. Y.					
2.	R587	Z5161	11RSF4	15RS4	23RSF4	11RS4	23RS4	15RSF4	101D2A	105D2V	105D8D	113D8H	113D1D	113D2G
3.	400	400	400	400	400	400	400	400	400	400	1000	1000	60	400
4.	16	115	26	40	90	40	90	40	26	15	24	24	60	60
5.	---	---	---	---	---	---	---	---	---	---	---	---	---	400
6.	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7.	± 7	---	± 5	± 4	± 3	± 5	± 5	± 4	---	± 5	± 5	± 5	± 5	---
8.	1.7	0.41	2.3	1.5	0.7	1.5	0.7	1.5	2.3	1	0.8	0.8	1	1
9.	0.14	0.000095	0.2	0.2	---	0.2	0.2	0.2	0.3	± 0.1	0.2	± 0.2	± 0.2	± 0.2
10.	1.0001 ± 0.0015	0.7826	0.975	1.000 ± 0.005	0.975	1.005 ± 0.005	1.005 ± 0.005	0.870	0.846 ± 0.034	0.98 ± 0.01	1.00 ± 0.01	1.000 ± 0.010	1.0 ± 0.01	1.027 ± 0.01
	---	---	0.985	---	0.985	---	---	0.960	---	---	---	---	---	---
11.	0.017 ± 0.058	---	---	8.5	---	6	---	---	13.5 ± 1	8.5 ± 0.5	5.8 ± 1	1.9 ± 1	28.8 ± 0.5	1.3 ± 0.5
	---	---	---	---	---	---	---	---	---	---	---	---	---	---
12.	15	25	11	15	23	11	23	15	11	15	15	23	23	23

COMPONENTS DIGEST

SUMMARY OF INDUCTION RESOLVER CHARACTERISTICS (CONTINUED)

1.	CO. NAME AND ADDRESS	John Oster Mfg. Co. Racine, Wisconsin				Reeves Instrument Corp. Garden City, New York				Wright Mach. Co. Durham, N. C.	
2.	MODEL NUMBER	4015-05	4061-01	4111-02	4261-01	R150H-102	R600-101	R601-102	R151-102	20D330-2	20D334-2
3.	FREQUENCY (cps)	400	400	400	400	400	60	400	400	400	400
4.	INPUT VOLTAGE (volts)	26	26	26	26	50	50	100	60	24	24
5.	LOW CORNER FREQUENCY (cps)	---	---	---	---	24	8	20	42	---	---
6.	PEAKING FREQUENCY (cps) uncompensated	---	---	---	---	125k	30k	30k	---	---	---
	PEAKING FREQUENCY (cps) compensated	---	---	---	---	---	---	---	60k	---	---
7.	MAX. PERPENDICULARITY OF AXIS (minutes)	---	---	---	---	± 5	± 3	± 3	± 5	± 5	± 4
8.	TOTAL NULL VOLTAGE (mv/volt input)	---	---	---	---	1	1	1	1	0.5	14
9.	MAXIMUM FUNCTIONAL ERROR (percent)	20 min. spread	24 min. spread	20 min. spread	± 7	0.1	0.05	0.05	0.1	± 0.10	0.16
10.	TRANSFORMATION RATIO primary to secondary	0.685	0.454	0.454	0.454	0.955 ± 0.015	0.975 ± 0.020	0.975 ± 0.020	0.980 ± 0.020	0.248	0.871 ± 0.15
	TRANSFORMATION RATIO compensator primary to secondary	---	---	---	---	---	---	0.985 ± 0.015	0.985 ± 0.010	---	---
11.	TIME PHASE SHIFT (degrees) primary to secondary	8.77	14.6	7.5	15	3.5 ± 1.0	8.5 ± 2.0	3 ± 0.8	6 ± 2	9	14.5
	TIME PHASE SHIFT (degrees) compensator primary to secondary	---	---	---	---	---	---	0.0	0.0	---	---
12.	FRAME SIZE	15	10	11	8	15	23	23	15	15	15

1.	CO. NAME AND ADDRESS	Vernitron Corp. Carle Place, L. I., N. Y.			
2.	MODEL NUMBER	VRE23/41-4a	VRD23/41-6a	VRB15/20-4a	VRA11/22-4a
3.	FREQUENCY (cps)	400	60	400	400
4.	INPUT VOLTAGE (volts)	0.5-130	0.5-26	1-70	0-30
5.	LOW CORNER FREQUENCY (cps)	14	14	40	35
6.	PEAKING FREQUENCY (cps)	120k	120k	65k	55k
7.	MAX. PERPENDICULARITY OF AXIS (minutes)	± 2.5	± 3	± 2.5	± 2.5
8.	TOTAL NULL VOLTAGE (mv/volt input)	0.5	0.75	0.5	0.5
9.	MAXIMUM FUNCTIONAL ERROR (percent)	0.03	0.05	0.05	0.05
10.	TRANSFORMATION RATIO primary to secondary	0.980 ± 0.01	0.980 ± 0.01	0.980 ± 0.01	0.980 ± 0.01
	TRANSFORMATION RATIO compensator primary to secondary	0.975 ± 0.01	0.975 ± 0.01	0.975 ± 0.01	0.975 ± 0.01
11.	TIME PHASE SHIFT (degrees) primary to secondary	1.9 ± 0.5	12 ± 1.5	8.5 ± 0.5	11 ± 1
	TIME PHASE SHIFT (degrees) compensator primary to secondary	0	0	0	0
12.	FRAME SIZE	23	23	15	11

WORTH FILING

Linear Ball Bushings

20 page catalog describes miniscule linear ball bearings that will enable major reductions in both the size and weight of critical instruments and accessories in missiles and aircraft. The new ball bushings, designated INST-258 and INST-396, are for use on shaft diameters of 0.1246″ and 0.1871″. Overall dimensions are: O.D. 0.3125″; length, 0.5″, 0.375″ and 0.562″. Units weigh 0.15 and 0.30 oz. Despite small size, each bearing contains three complete ball circuits with each circuit containing 16 balls in the smaller and 17 balls in the larger ball bushing.

In addition, possessing all the characteristics of the larger and heavier instrument bushings, the units are extremely rugged in construction and capable of withstanding high vibrational and shock loads.

Source: Thomson Ind., Inc.
Manhasset, N. Y.

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Power Transmission Equipment

468 page general engineering catalog describes a line of mechanical power transmission equipment. Various sections of the catalog are devoted to both new and established product categories, with engineering drawings, dimensions, weights, prices, technical data in tabular forms, and many pages of selection and application information. Among the products included are compact V-belt drives, flexible cushion couplings and torque-arm speed reducers.

For your copy: Write on Company Letterhead to:
Dodge Manufacturing Corporation
Michawaka, Indiana

Ceramic Insulated Wire

20-page brochure covering ceramic insulated wire for use in high temperature and nuclear applications outlines many of the pitfalls which must be avoided if components are to operate successfully at temperatures in the 800 to 1200 F range. Part one is devoted to the physical and electrical properties of the insulation over an extended temperature range. The next section contains information on conductors which may be used successfully under various conditions. The last section concerned with potting, sealing and termination has invaluable information on potting cements.

Source: Secon Metals Corporation
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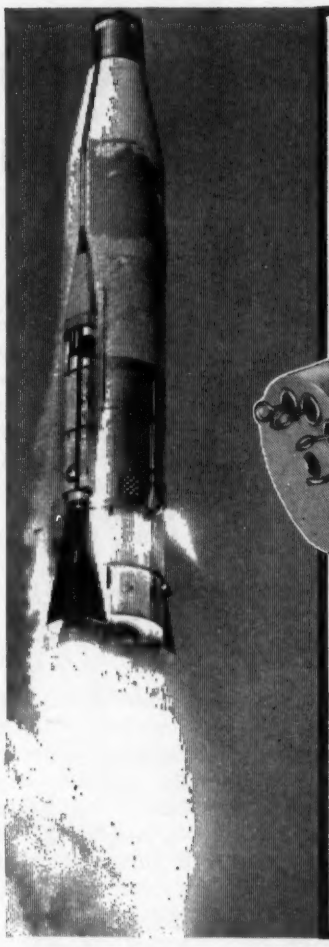
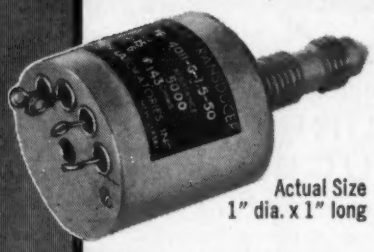


LIGHT WEIGHT ONE OUNCE MAX.
SMALL SIZE ONE CUBIC INCH MAX.
MINIATURE PRESSURE TRANSDUCER



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High vibration performance
±35G to 5,000 cps
Pressure ranges
Absolute, differential and gage pressures
0-1 to 0-400 psi
Differential pressures
±3 to ±200 psi

Standard Nominal Potentiometer Resistances
400 to 10,000 ohms
Electrical Connection
Pigmy receptacle or soldering terminals
Mounting
Flange or bulkhead

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Write us regarding your transducer requirements.

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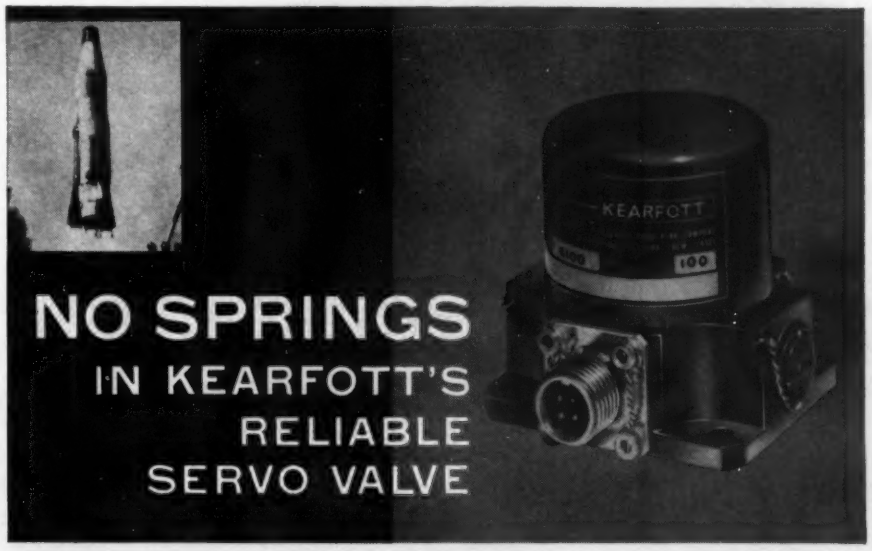

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KEARFOTT DIVISION
Little Falls, New Jersey

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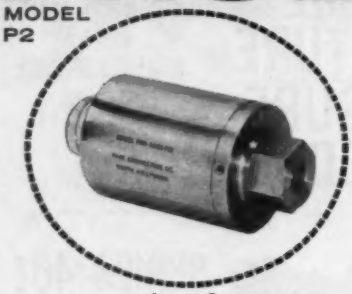
PACE
MODEL P2



magnetic reluctance
PRESSURE TRANSDUCER

Ranges: 200 to 10,000 psi — Gage or Absolute.

Pressure Media: Corrosive liquids, gases and solid suspensions.

Insensitive to Shock and Vibration.

PACE's Model P2 is designed for static and dynamic measurement in missile, aircraft, laboratory and ground test applications.

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Pressure Transducers

One in. diameter pressure transducer measures up to 15,000 psi and weighs less than 0.25 lbs. The pressure sensing element is a twisted tube which moves a wiper across the winding of a precision potentiometer in response to changes in pressure. Pressure and potentiometer elements are enclosed in a sealed case. Colvin Labs., Inc., East Orange, N.J.

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Potentiometers

¾" plastic case potentiometer completely meets Mil-R-19A and Mil-R-19/1A. "O" ring shaft seal and complete internal sealing provides the same protection as encapsulation in less space. Resistance range, ±5%, is one to 20,000 ohms. Electrical and functional rotation is 355° without stops; 300° with stops. Waters Mfg., Wayland, Mass.

Write No. 688 in Box on Inquiry Card

Latching Relay

Non-magnetic latching relays mechanically lock in either open or closed position and require a new command pulse each time before they can be reactivated or moved in any way. The relays function on the plug-in principle, assuring positive contact under extreme conditions, and permitting a load up to 20 amps at 26.5 v dc (resistive). Operation of the relay is achieved by a single solenoid with a double plunger. The plungers connected to a ratchet mechanism constitute a completely balanced assembly of maximum resistance to shock and vibration loads. Astromics, Glendale, Calif.

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Strain Gage Accelerometer

Claimed to be the smallest of its type, a linear unbonded strain-gage bi-directional device measures accelerations perpendicular to a mounting surface. Weighing less than three ozs., the one-cu.-in. temperature accelerometer has a rated linearity and hysteresis of less than ±0.75% of full range output. A non-pendulous type mass suspension permits exceptionally low cross-axis sensitivity of less than 0.01 g/g for an input of three times the rated range. A very low viscosity oil keeps viscosity changes to a minimum during low and high temperature applications. Temperature compensation insures reliable static accuracy for the −65 to 250 F temperature range. Consolidated Electrodynamics Corp., Pasadena, Calif.

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Control Module

Rugged, compact size 11 servo motor/gearhead/pot. module coverts a rotary mechanical position to an electrical functional signal. The module performs with a high degree of reliability of over 1,000,000 cycles of life and a maximum resolution of 0.046% even when subjected to extremes in vibration, shock, acceleration or environment. The unit is said to be the only module of this type supplied with an output shaft for test and checking purposes. Module can be supplied with a servo motor generator in place of the servo motor without any decrease in reliability. Guidance Controls Corp., Hicksville, N.Y.

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for use in conjunction with
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Gold Wire for Mesa Bonding

Gold Wire, 99.99% pure, is available in any size down to .0005". Supplied in various tempers as required . . . Recent developments indicate that an alloy of 2% Platinum—98% Gold may be successfully used for this application. It is somewhat stronger than pure gold.

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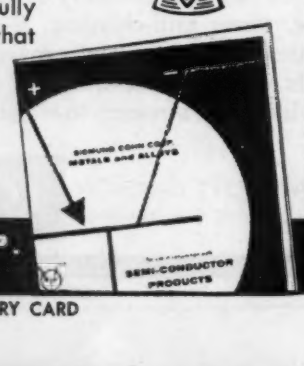

SIGMUND COHN CORP.
121 So. Columbus Ave. • Mt. Vernon, N. Y.

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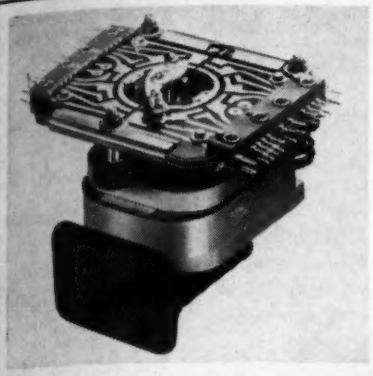

Rotary Stepping Switch

Electromagnetic stepping switches consisting of high speed stepping motors and printed circuit switch decks provide true digital behavior up to 240 steps or 12 revolutions per second. The stepping motor has no ratchets, pawls, mechanical stops or brushes, thus it has an extremely long operating life—averaging 25,000,000 revolutions with light loads and adequate arc suppression. The switch stops instantly at any predetermined position on the switch deck. The flush printed switch decks are available in various combinations to meet specific needs. Sigma Instruments, Inc., So. Braintree, Mass.

Write No. 679 in Box on Inquiry Card

Resolvers & Synchros

Computing resolvers of 0.05% accuracy are capable of withstanding 500 v dc between stator and compensator for 1000 hours. Units contain either non-bifilar or bifilar compensating windings. In 23, 15, and 11 frame sizes, the resolvers have an inter-axis error of ±2½ minutes. All units meet MIL R-14346. Size 8 synchros have high accuracy and stability over the temperature range from −55 to +125 C and are available in two types of terminal blocks. Maximum electrical errors of ±5, ±7, and ±10 minutes can be specified for all synchros with standard 11.8 volt input as well as synchro transmitters with 115 volt input and 11.8 volt output. Vernitron Corp., Carle Place, L. I.

Write No. 304 in Box on Inquiry Card

Unidigit Pulse Counter

Single wheel electromagnetic counter designed for parallel entry may be stacked on common studs to the number of decades desired. The number wheels with digits 0-9, 3/16″ high, are positioned individually by pulse at stepping rates to ten per sec. Provision is made for automatic reset to zero. Presin Co., Santa Monica, Calif.

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Kearfott's rugged shaft position-to-digital converters are resistant to high shock and vibration and high and low temperature environments. Ideally suited for missile applications, these converters are available for many uses, including latitude, longitude, azimuth or conventional angular shaft displacement conversion and decimal count conversion. Exclusive drum design provides large conversion capacity (typical unit 2^{15}) in smallest available size. Combination counter-converter assemblies for both visual and electrical readout also available.

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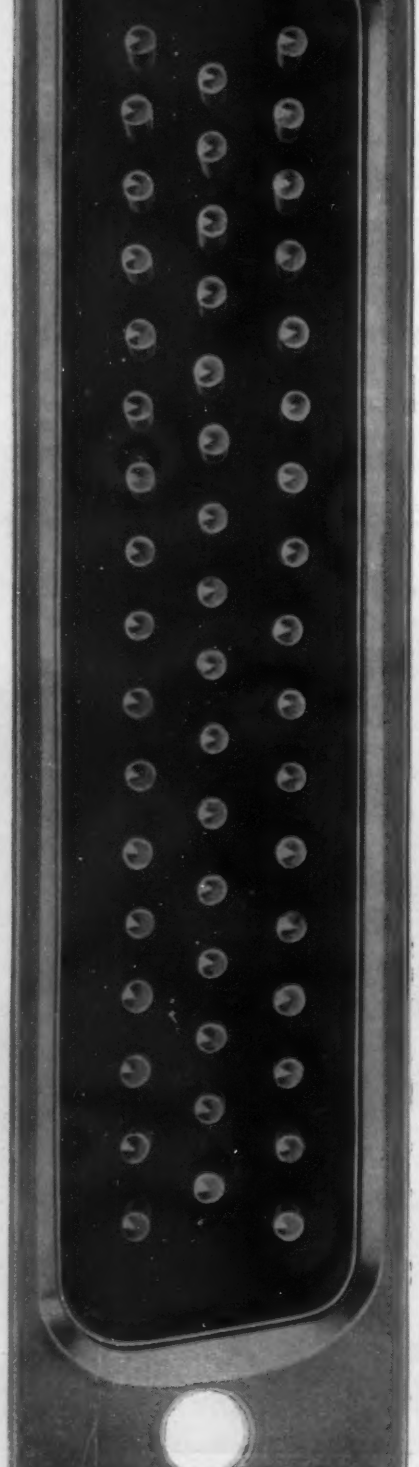

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CANNON GOLDEN-D SUBMINIATURE PLUGS

DESIGNED ESPECIALLY FOR MISSILE CIRCUITRY AND MAXIMUM RELIABILITY APPLICATIONS

The "Golden-D" Cannon Plugs are engineered to deliver superior performance in a subminiature size! Supplementing our famous standard D-Subminiature line, the "Golden-D" has these new design features: • MONOBLOC INSULATORS • PROBE-PROOF CLOSED-ENTRY SOCKET CONTACTS • LOW ENGAGEMENT/SEPARATION FORCES • GOLDEN CADMIUM SHELL FINISH • MATES WITH ANY CANNON "D" OF SAME SIZE AND LAYOUT. Wherever maximum reliability is needed in a subminiature multi-contact plug—for both military and industrial applications—ask for the new "Golden-D"...another reason why you should contact the world's most experienced plug manufacturer for *all* your plug requirements. The "Golden-D" is available in four types with a large variety of contact layouts. For further information write to:

CANNON PLUGS

CANNON ELECTRIC COMPANY, 3208 Humboldt St., Los Angeles 31, Cal

CIRCLE NO. 67 ON INQUIRY CARD

Overheat-Protected Motor

Motor protection is based on the sensitivity of positive temperature coefficient thermistors to heat build-up in the motor winding alone, rather than being affected by line currents. The "Guardistor" motor can be used for any ac application and protects against overheating due to: single phasing, locked rotor, frequent starting, repeated overloads, high ambient temperatures, abnormal voltage conditions, ventilation failures, switch welding (on single-phase motors) and plugging or reversing duties. The contactless thermistor, a semiconductor, is an integral part of the motor; encapsulated in epoxy resin before installation in the motor winding. The encapsulation, plus the motor insulation, provides resistance to moisture, chemicals and oils. Westinghouse Electric Corp., Pittsburgh, Pa.

Write No. 422 in Box on Inquiry Card

Miniature Connector

Especially suited for electronic cooling applications, a miniature fluid connector contains an automatic push-pull device for quick connect-disconnect operation. Weighing exactly one ounce, the unit withstands pressures up to 5000 psi and temperatures from —20 to 400 F. It is normally made of aluminum with Viton "A" seals, although stainless steel and various elastomers are available. Wiggins Oil Tool Co., Inc., Los Angeles, Calif.

Write No. 686 in Box on Inquiry Card

2 Gram Potentiometers

Miniature precision trimming potentiometers with a circular aluminum housing surrounding the enclosed mandrel, is a half inch in diameter, a fifth of an inch thick and weighs less than two grams. Bonding every resistance turn to the mandrel permits greater wiper tension. Setting stability, even under environmental extremes, is assured by the 40-to-1 worm-and-gear adjustment. The adjustment screw projects approximately a sixteenth of an inch from the side of the housing. Standard resistance values range from 10 to 50,000 ohms with continuous wiper rotations. Temperature range is from 55 to 150 C; vibration 30 g's, 10 to 2000 cps; shock 50 g's, 11 msec duration; altitude 50,000 ft and unit meets Mil-E-5272A. Handley, Inc., Los Angeles, Calif.

Write No. 420 in Box on Inquiry Card

ELGIN ADVANCE RELAYS
POWER TYPE RELAYS FROM STOCK
POWER CONTROL TYPES
TYPE | CONTACTS* | COIL VOLTAGE (VAC)
PC/1C | SPDT 15A | 6, 12, 24, 115, 220
PC/2C | DPDT 15A | 6, 12, 24, 115, 220
PC/3C | 3PDT 15A | 6, 24, 115, 220
PC/4C | 4PDT 15A | 6, 24, 115, 220
COIL VOLTAGE (VDC)
PC/1C | SPDT 15A | 6, 12, 24, 110
PC/2C | DPDT 15A | 6, 12, 24, 110
PC/3C | 3PDT 15A | 6, 12, 24, 110
PC/4C | 4PDT 15A | 6, 12, 24, 110
COIL VOLTAGE | COIL RES. DC (OHMS)
PG/2C/6VA | DPDT 15A | 6 VAC | 1.4
PG/2C/24VA | DPDT 15A | 24 VAC | 25
PG/2C/115VA | DPDT 15A | 115 VAC | 400
PG/2C/220VA | DPDT 15A | 220 VAC | 1600
PG/2C/6VD | DPDT 15A | 6 VDC | 16
PG/2C/12VD | DPDT 15A | 12 VDC | 63
PG/2C/24VD | DPDT 15A | 24 VDC | 250
PG/1Z/6VD | SPDT 30A | 6 VDC | 16
PG/1Z/115VA | SPDT 30A | 115 VAC | 400
POWER TRANSFER TYPES
PH/1A/6VD | SPSTNO 20A | 6 VDC | 16
PH/1A/115VA | SPSTNO 20A | 115 VAC | 400
PH/1C/6VD | SPDT 20A | 6 VDC | 16
PH/1C/115VA | SPDT 20A | 115 VAC | 400
PV/1A/6VD | SPSTNO 30A | 6 VDC | 16
PV/1A/115VA | SPSTNO 30A | 115 VAC | 450
PV/1C/6VD | SPDT 30A | 6 VDC | 16
PV/1C/115VA | SPDT 30A | 115 VAC | 450
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MINIATURE, HIGH PERFORMANCE
MAGNETIC BRAKE CLUTCHES
Typical applications involving these Size 11 magnetic clutches, brake clutches, and brakes include service as output controls in mechanical differential computers, as motor brakes, and as speed changers and uncouplers. Kearfott can also provide magnetic clutches, brake clutches and brakes in various other sizes to suit desired applications. Unit illustrated features clutch torque of 4 in. oz. and brake torque of 6 in. oz.
KEARFOTT DIVISION
Little Falls, New Jersey
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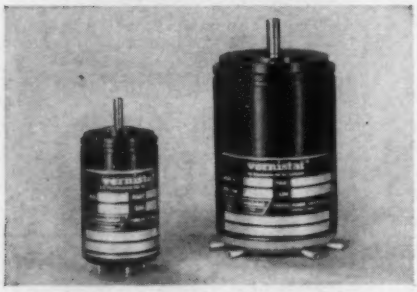
Other Divisions: GPL, Librascope, Link

CIRCLE NO. 69 ON INQUIRY CARD

vernistat®
design report

Information on Vernistat a.c. potentiometers for design engineers

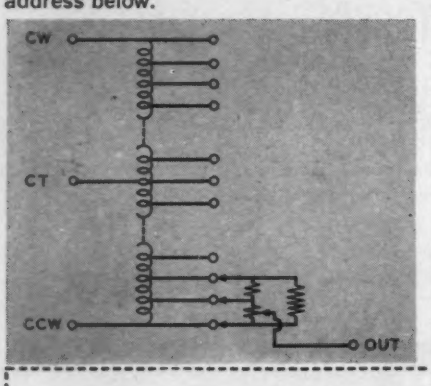
A FISTFUL OF CONTROL



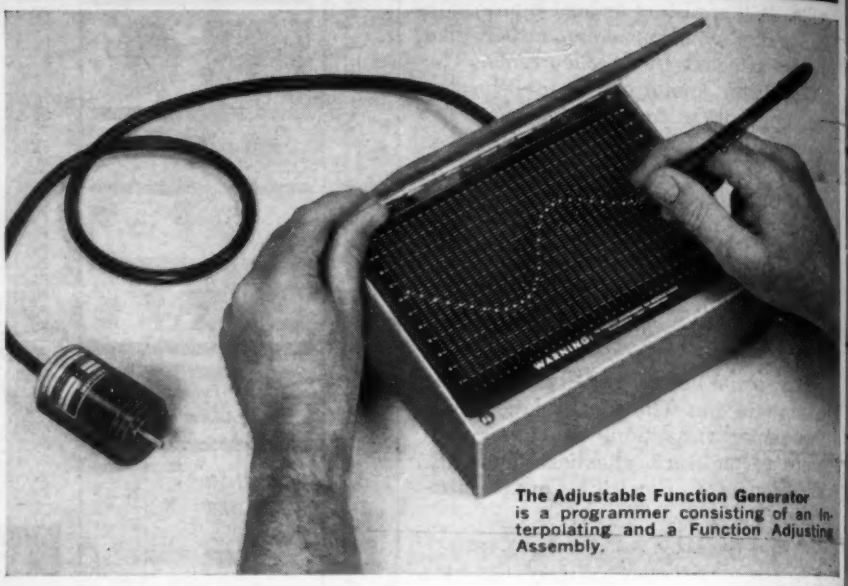
To call the Vernistat a precision a.c. potentiometer is correct . . . to say that it has high linearity, high resolution, and low phase shift is also correct . . . but none of this goes far enough. This servo design component can also be defined as: A precision circuit element that multiplies input voltage by some function of shaft position . . . (this gladdens the hearts of computer people). An essentially nondissipative voltage divider that stays cool. A pot with its own built-in transformer . . .

Even the circuit diagram (shown below) leaves a lot unsaid. As you see, it fails to show the Vernistat's continuous rotation (up to 30 turns!) that stretches the voltage scale for super-accuracy. It ignores the fact that Vernistat has continuous rotation, that is, it goes **forward** instead of backward to its initial position.

This unique component deserves a long, searching look from every designer of accurate electronic equipment. You can use it to achieve phase inversion, step up voltage, generate mathematical functions. It eliminates isolation amplifiers in analog equipment . . . can be used as a low-impedance source, attenuator, feedback control. Find out how the Vernistat can help make your electronic systems more simple, compact, accurate and reliable by writing to the address below.



Get on the mailing list for Vernistat Design Reports. Packed with ideas. Ask us.



The Adjustable Function Generator is a programmer consisting of an Interpolating and a Function Adjusting Assembly.

FOR A NON-LINEAR SIGNAL OUTPUT—THE VERNISTAT ADJUSTABLE FUNCTION GENERATOR

See that curve on the panel? You adjust it by hand . . . any shape, real quick! You draw your own Y = f (X) curve and pull out a repeating, nonlinear voltage to control the process you require.

Almost any process that can be controlled by a varying voltage can be controlled by the signal from a Vernistat Adjustable Function Generator.

Here's the story:

In the Vernistat, the autotransformer uses equally spaced taps, giving a highly linear output. These taps can be crowded or spread apart, in which case you get a permanent, nonlinear output related to their spacing. In the Function Generator, the autotransformer has 101 equally spaced taps which **you can select** to form the nonlinear function you desire. Using 34 sliders, you set your voltage up and down the Y-axis, graphing the Y-values against X. The X-axis represents angular position of the shaft over a range of 10 shaft turns.

Actually, the entire Function Adjustable Assembly is nothing more than a switch for pulling the proper curve out of the Vernistat. Once the curve is set an Interpolating Vernistat provides for a smooth voltage output between taps. The steel case of the Assembly is 3 x 7 x 8 inches, which shows you how compact the mechanism is.

APPLICATIONS

You can use the Function Generator both as a lab instrument and a system component. Some important uses are:

1. Rapid Empirical Determination of Functions: Eliminates time-consuming mathematical calculations and the production and wiring of a large number of special padding resistors. Once a curve is determined, a nonlinear Vernistat can easily be constructed to provide a simplified, permanent, function-generating unit.

2. Linearization: The Function Generator can be used to compensate for nonlinearities in electronic systems. It can be placed in series with the signal to be corrected or used as a nonlinear feedback element in a servo loop.

3. Input to Analog Computer: It converts nonlinear data to an electrical input.

4. Control and Programming: Used in chemical, petrochemical and other continuous processes to control a variety of functions. If the shaft is rotated at constant speed, control will be a function of time.

Several series of Vernistats are available for use with the Function Generator. For a complete description drop us a line.

vernistat® division

PERKIN-ELMER CORPORATION • 768 Main Avenue, Norwalk, Connecticut

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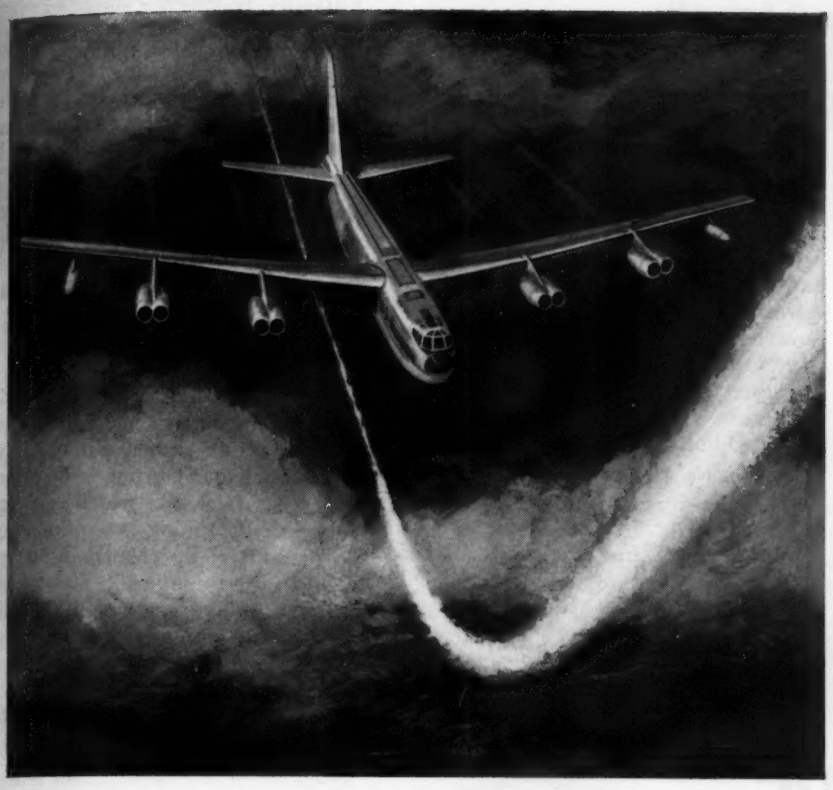

KEARFOTT is producing

precision floated gyros for the

Skybolt missile

***Engineers:** Kearfott offers challenging opportunities in advanced component and system development.*

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Other Divisions: GPL. Librascope. Link

CIRCLE NO. 71 ON INQUIRY CARD

New Electronic Components For Electromechanical Systems

Molded Jack

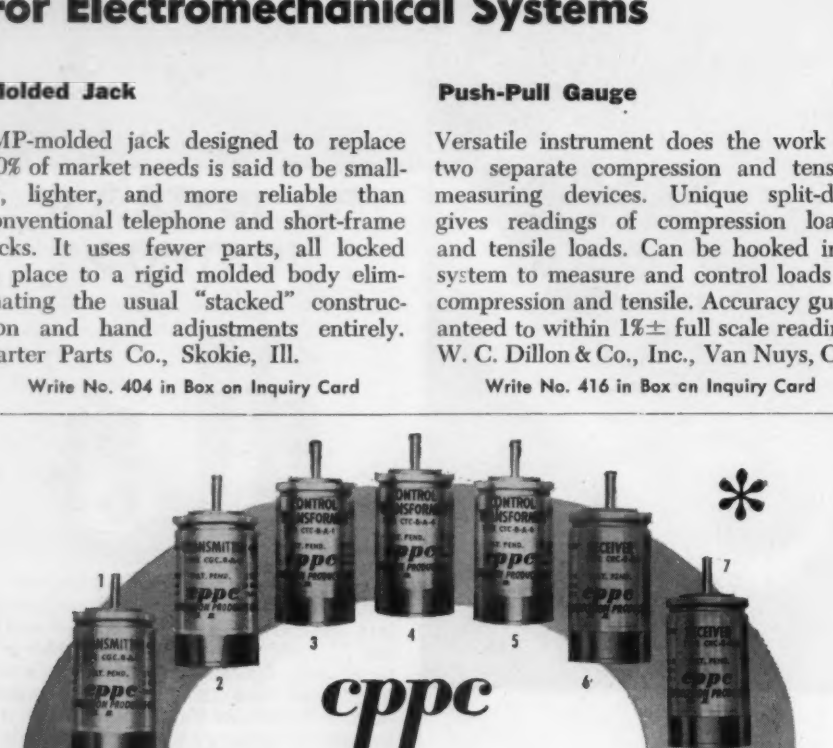
IMP-molded jack designed to replace 90% of market needs is said to be smaller, lighter, and more reliable than conventional telephone and short-frame jacks. It uses fewer parts, all locked in place to a rigid molded body eliminating the usual "stacked" construction and hand adjustments entirely. Carter Parts Co., Skokie, Ill.

Write No. 404 in Box on Inquiry Card

Push-Pull Gauge

Versatile instrument does the work of two separate compression and tensile measuring devices. Unique split-dial gives readings of compression loads and tensile loads. Can be hooked into system to measure and control loads in compression and tensile. Accuracy guaranteed to within 1%± full scale reading. W. C. Dillon & Co., Inc., Van Nuys, Cal.

Write No. 416 in Box on Inquiry Card



* A Partial Showing

Clifton Precision's size 8 rotary components have been tried and proven by customers over the past 4 years. More than 50,000 have been shipped. These are the most accurate and best tested (because they are use tested) size 8 rotary components on the market today.

1. Torque transmitter (26v. input) 2. Torque transmitter (115v. input) 3. Control transformer (lo Z) 4. Control transformer (hi Z) 5. Control transformer (very hi Z) 6. Torque receiver (26v. input) 7. Torque receiver (115v. input) 8. Torque differential (lo Z) 9. Torque differential (hi Z) 10. Electrical resolver (.5 t.r.) 11. Precision computing resolver (feedback winding) 12. Electrical resolver (1 t.r.) 13. Linear transformer (115v. input) 14. Linear transformer (26v. input) 15. Servo motor (1" length, .40 in-oz stall torque) 16. Motor generator (10v. input) 17. Servo motor (53/64" long) 18. Servo motor (35v. center tap) 19. Servo motor (26v. center tap) 20. Motor generator (26v. input) 21. Servo motor (.30-in-oz stall torque) 22. D.C. motor (14v. input) 23. D.C. motor (28v. input)

CLIFTON PRECISION PRODUCTS CO., INC.

CLIFTON HEIGHTS, PA.

Sales Office: 5050 State Rd., Drexel Hill, Pa.—MAdison 2-1000, TWX LNSDWN, PA. 1122 (u).

cppc

CIRCLE NO. 72 ON INQUIRY CARD

Variable Resistor

1½ watt wirewound variable resistor is said to be 1/3 smaller than similar units. Designed especially for high reliability applications, the unit meets Mil-R-19 and is recommended for high temperature operation up to 125C. It measures 11/16" in diameter and 5/16" in depth and has a ¼" dia. stainless steel shaft. Centralab, Milwaukee, Wis.

Write No. 405 in Box on Inquiry Card

Timing Relay

Highly flexible, transistorized, printed circuit time delay relay can be either horizontally or vertically mounted within its package. Output is operated by a transistorized gate which is energized from an RC timing network. Accuracy is guaranteed by regulated power applied to the timing unit. Standard units with a timing range of 100 milli-seconds to 60 seconds are said to offer fast recycle, transient protection, voltage compensation, reverse polarity protection and high resistance to extreme environments. Leach Corp., Los Angeles, Calif.

Write No. 406 in Box on Inquiry Card

Power Supply

Transistorized dc power supply is said to provide a precise output at extremely low voltages. Adjustable output voltage ranges from zero to 36 volts dc at 15 amps. Especially designed for powering critical transistor circuits, the unit includes highly efficient filtering and rapid recovery from line or load transients, providing a smooth, "spike-free" output. Except for the forced-air cooling blower motor which must be of proper specific frequency rating, the supply will operate over the 50 to 400 cps range with no interference from input frequency. Sorensen & Co., South Norwalk, Conn.

Write No. 407 in Box on Inquiry Card

Electro-Optical Relay

Without moving parts, an electro-optical relay with a conductance on-off ratio of 1,000,000 to one is capable of speeds up to 100 operations per second. Smaller than a cigarette, the device can replace a substantial portion of re-lays, potentiometers and commutators. Named the Raysistor, the unit includes a light source in the control end, which, when excited, actuates a photo-conductor in the signal end, allowing either ac or dc information to pass. The Raysistor has an "on" life of 2500 hours, irrespective of the number of switching operations and can switch without introducing transients in the signal circuit. Raytheon, Newton, Mass.

Analog-Digital Converters

128-count per revolution, true binary read-out and non-ambiguity are claimed for encoders which have a drum construction of rhodium-plated silver or solid gold segments firmly embedded in epoxy resin and diamond turned to 6 micro-inch stepless finish. Brushes are compatible spring-temper, precious metal 3-strand brooms. Uniform wear and life expectancy is said to be far in excess of conventional printed circuit disc commutators. Airflyte Electronics Co., Bayonne, N.J.

Write No. 721 in Box on Inquiry Card

Power Rectifiers

Single unit silicon power rectifiers with current ratings from 200 ma through 10 amps eliminate the need for a series connection of lower voltage multiple units to achieve a PIV of 2200 volts. Units are hermetically sealed, have an operating temperature range from −60 to +150 and a low forward voltage drop not exceeding two volts. Britton Electronics, Mount Vernon, N.Y.

Write No. 302 in Box on Inquiry Card

Primary Batteries

Automatically activated by a reliable solid-propellant gas mechanism which has only one moving part, silver-zinc batteries produce a maximum current of 400 amps with a discharge time of 1.8 minutes. Application of an activation signal of 4 amps, 28 volts, ignites the solid propellant which creates gas to force electrolyte into cells. Activation time is 0.8 second and double ignition circuit prevents activation failure. Units withstands accelerations of 50 g, shocks of 50 g and vibrations of 30 g along all three major axes. Ambient temperature range is 60 to 100 F with special models for −65 to +165 F. Cook Batteries, Denver, Col.

Write No. 447 in Box on Inquiry Card

Servo Amplifier

Designed to operate typical two-stage electrohydraulic servovalves, a dc amplifier produces a differential current in the valve torque motor coils which is proportional to the voltage applied at the amplifier input. Included in the amplifier assembly are two regulated and stabilized power supplies. A variable frequency (as low as 200 cps, and up to 600 cps) dither signal generator minimizes the effect of friction in the mechanical components of the servosystem. The company also offers a complete servopack containing a servovalve, actuator, pump and controls. Eastern Ind., Inc., Hamden, Conn.

Write No. 675 in Box on Inquiry Card

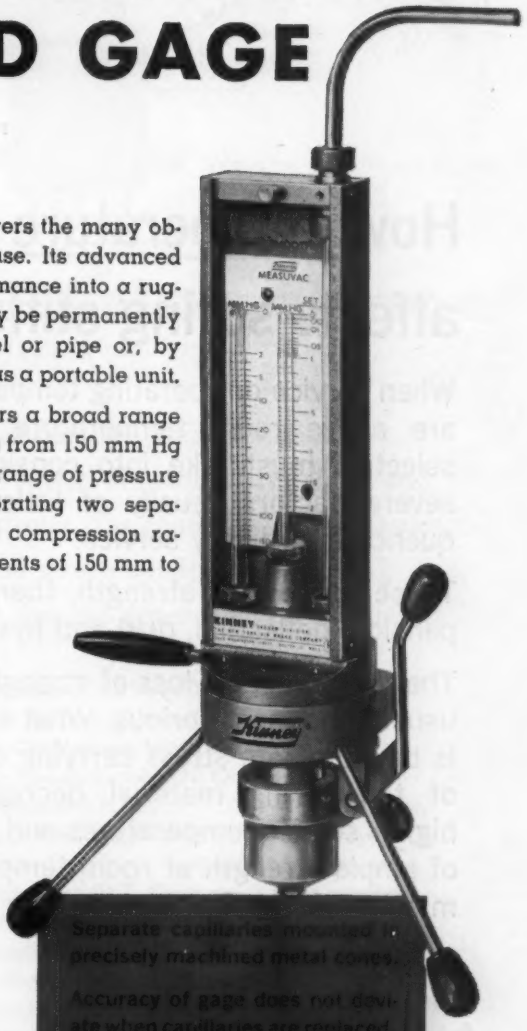
Kinney®

PRESENTS A

much smaller

~~BIGGER~~ and BETTER

McLEOD GAGE



The KINNEY McLeod Gage answers the many objections to other gages now in use. Its advanced design compacts superior performance into a rugged, versatile instrument that may be permanently mounted on bracket, tank, panel or pipe or, by affixing demountable legs, used as a portable unit.

The KINNEY McLeod Gage covers a broad range of pressures... accurate readings from 150 mm Hg to 1 Micron Hg. This exceptional range of pressure readings is achieved by incorporating two separate capillaries having separate compression ratios, making available measurements of 150 mm to 2 mm and 2,000 microns to 1 micron. Unlike other McLeod Gages, the reading capillary tubes are completely separate and replaceable – easily detached from the main body at the knurled sealing glands. Because these tubes are reproducible, complete accuracy between each gage is assured.

The KINNEY McLeod Gage requires less mercury and it is supremely simple to add mercury, remove it for cleaning or recharge the gage. Operation requires no special skill . . . readings are achieved quickly, easily and confidently. Write for full information and prices today.

Separate capillaries mounted in precisely machined metal cones.

Accuracy of gage does not deviate when capillaries are replaced.

All parts easily accessible for cleaning and maintenance.

Easier to read . . . light weight . . . sturdy . . . more compact.

Get all the facts on the NEW KINNEY McLEOD GAGE. Write today!

KINNEY VACUUM DIVISION
THE NEW YORK AIR BRAKE COMPANY
3521 WASHINGTON STREET • BOSTON 30 • MASS.

Please send me Bulletin No. 3821.1 and prices on the KINNEY McLeod Gage.

Name_____

Company_____

Address_____

City_____ State_____

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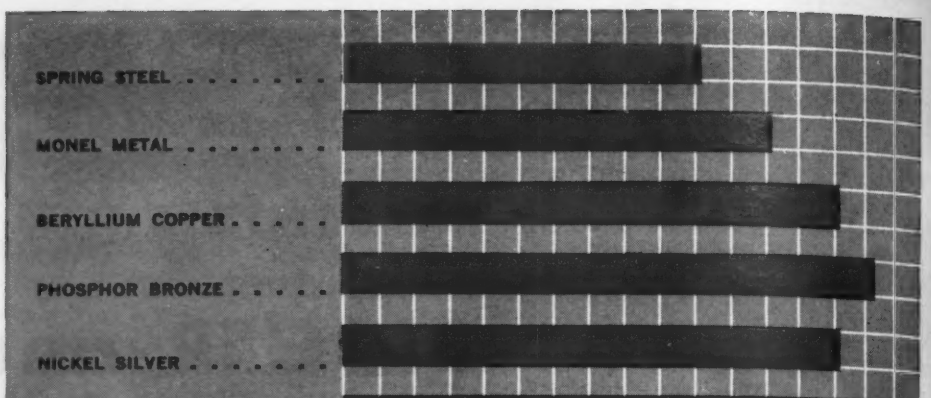


PER CENT DECREASE IN STIFFNESS WITH 100°F. INCREASE IN TEMPERATURE

How Temperature affects spring stiffness

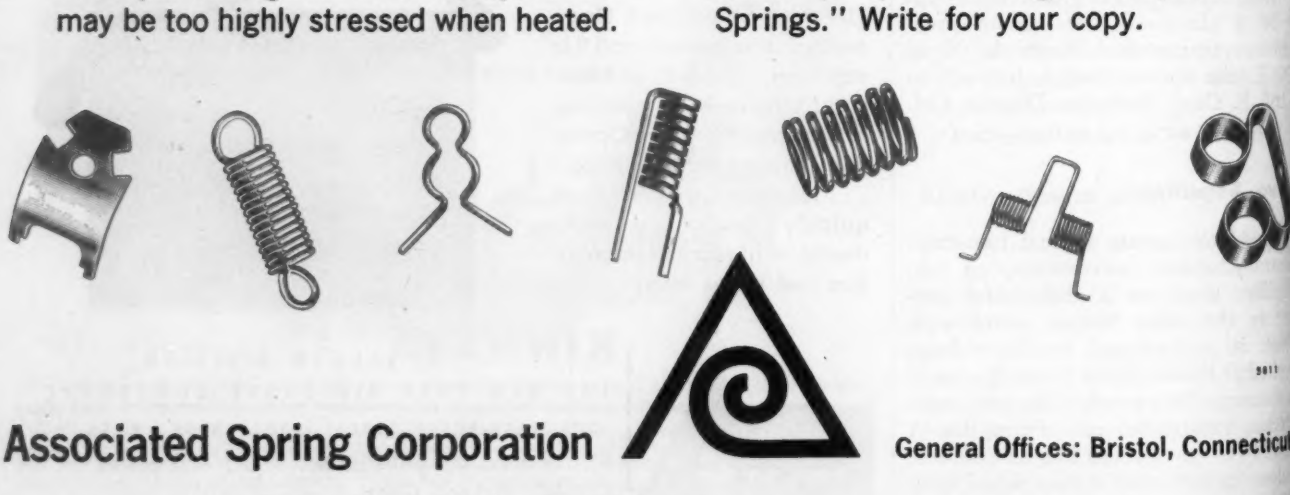
When service or operating temperatures are above room temperature, spring selection must take into consideration several factors usually of little consequence in ordinary service.

These are loss of strength, thermal expansion, deflection, drift and hysteresis.

The first effect — loss of strength — is usually the most serious. What happens is that the safe stress carrying capacity of the spring material decreases at higher service temperatures and springs of ample strength at room temperature may be too highly stressed when heated.

These effects may be small in many cases, but under some conditions they may be important, particularly when temperatures vary over a wide range. Where an accurately determined spring strength at elevated temperature is desired, the specifications covering load test at room temperature should be corrected for the change that will occur. The approximate amount of correction for 100° F change in temperature for various materials is shown in the chart above.

With today's increasing high-temperature problems in many fields, proper spring selection is more than ever important. The subject is discussed in our latest pamphlet, "High Temperature Springs." Write for your copy.



Associated Spring Corporation

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Dunbar Brothers Division, Bristol, Conn.
Wallace Barnes Steel Division, Bristol, Conn.
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Canadian Subsidiary: Wallace Barnes Co., Ltd., Hamilton, Ont. and Montreal, Que. Puerto Rican Subsidiary: Associated Spring of Puerto Rico, Inc., Carolina, P.R.

CIRCLE NO. 74 ON INQUIRY CARD

Receiving Tubes

Ten Pin, a new construction in miniature receiving tubes, combines multiple circuit functions in a single bulb or envelope. The company states that the new design should substantially reduce chassis designing costs by simplifying circuitry and wiring. The unit utilizes the conventional 9-base pin arrangement with an additional pin centered in the pin circle. Sylvania Electric Products Inc., New York, N.Y.

Write No. 696 in Box on Inquiry Card

Magnetic Core Circuits

A compatible family of magnetic core circuits includes a wide selection of shift registers, pulse gates and core drivers. Designed for the frequency range 0 to 250 kc, the core circuits are said to offer versatility and a saving of space at a price lower than that of equivalent transistor circuits. Their ability to maintain one of two discrete states makes the units ideal for shift registers or counters. Flip-flop action is obtained with a single core whereas transistor circuits normally require two transistors for each flip-flop. Engineered Electronics Co., Santa Ana, Calif.

Write No. 697 in Box on Inquiry Card

Reference Source

Supply delivers preselected precise calibration voltages over the range of zero to ten volts from a constant impedance output of ten ohms. Absolute accuracy is better than 0.01% for line voltage variations or ± 10% over the temperature range from 40 to 125 F. Tracking accuracy is better than 0.005%. The chopper stabilized supply maintains a 30 day stability of better than 0.005%. Selection of ten programmed voltages is by mercury contactors with panel pushbutton or remote selection. Owen Labs, Inc., Pasadena, Calif.

Write No. 715 in Box on Inquiry Card

Military Resistors

Wire wound resistors exceed the requirements of Mil-R-26c with "V" characteristics. Units contain a newly developed enamel and have special alloy terminals which match the thermal expansion of tube and enamel. Tru-Ohm Products, Chicago, Ill.

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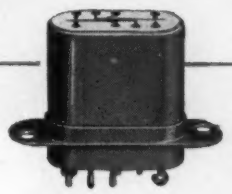
small... but **mighty**

COMAR'S SUB-MINIATURE TYPE SM



Less than an inch long — Weighs less than ½ oz.

big relay performance

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A high precision, efficient sub-miniature relay. Constructed to withstand severe vibration, heavy shock and temperature extremes. For control systems, missiles, computers, aircraft and similar applications requiring miniature size and dependable performance.

Nominal Coil Voltage: 26.5 Volts D.C.
Maximum Pull-In Voltage: 18 Volts D.C.
Maximum Drop-Out Voltage: 14 Volts D.C.
Coil Resistance: Approximately 570 Ohms.
Contact Arrangement: 2 P. D. T.
Contact Rating: 2 Amps. @ 28 V. D. C. Resistive (max.).
Maximum Operate Time (N.O. Contacts): 4 Milliseconds.
Maximum Release Time (N.C. Contacts): 3 Milliseconds.
Maximum Contact Bounce: 1 Millisecond.
Dielectric Strength: 1000 V. RMS, 60 Cycles (Sea Level).
Minimum Insulation Resistance: 100 Megohms.
Maximum Contact Resist: 0.05 Ohm; 0.10 Ohm (After Life).
Temperature Range: −65° to 125° C.
Operating Shock: 50 "G" for 11 Milliseconds.
Vibration: 20 "G"—5 to 2000 CPS.
Life: 100,000 Operations (Minimum).
Maximum Weight: .45 Oz.
Meets MIL-R-25018 and MIL-R-5757C specifications.

Send for Bulletin SM

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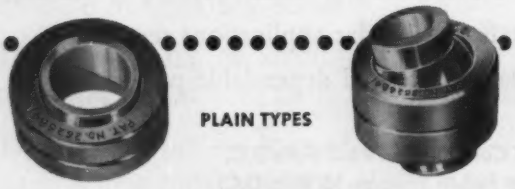

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CIRCLE NO. 76 ON INQUIRY CARD

WORTH FILING

Hydraulic Components

Twenty-four page catalog provides a single reference source on a complete line of pneumatic and hydraulic components. Included are product data and specifications on cylinders, drill units and valves. Booklet introduces an inter-changeable cylinder for air and oil.

Source: Alkon Products Corp.
Hawthorne, N.J.
For Your Copy: Write No. 805 in Box on Inquiry Card

Designing Power Supplies For V & M's

Twelve-page bulletin tells how to design power supplies for voltage-tunable magnetrons. Frequency and amplitude of the power output of VTM's is changed electronically by controlling voltages applied to the tube, thus proper use of VTM's is dependent on the designer's understanding of the effects of all voltages.

Source: General Electric
Schenectady, N.Y.
For Your Copy: Write No. 809 in Box on Inquiry Card

Filters and High Q Coil

Updated catalog offers complete information on electric wave filters and high Q coils. Detailed specs on stock items are given plus the extent of development in the art, providing the design engineer with a concept of the possibilities of present component design. An easy reference reactance-frequency chart is also included.

Source: United Transformer Corporation
New York, N.Y.
For Your Copy: Write No. 803 on Box on Inquiry Card

Precision Welding

Twenty-four page catalog describes stored-energy, capacitor-discharge power supplies; precision welding heads and hand-pieces; and welding accessories. Special section presents advantages of resistance welding, compares stored-energy welding to ac welding, and outlines important factors in selecting stored-energy equipment.

Source: Weldmatic Div., Unitek Corp.
Monrovia, Calif.
For Your Copy: Write No. 807 in Box on Inquiry Card

Gears and Speed Reducers

Two-hundred and forty-six page catalog contains information on sizes, ratings and specifications of a complete line of gears and speed reducers. Engineering data on the proper selection of gears and reducers to meet specific job requirements is included. Types covered include: 14½ and 20 degree pressure angle spur gears, bevel gears, mitre gears, worm and worm gears, spiral bevel gears, racks and sprockets. One section is devoted to a new series of fin and fan cooled speed reducers.

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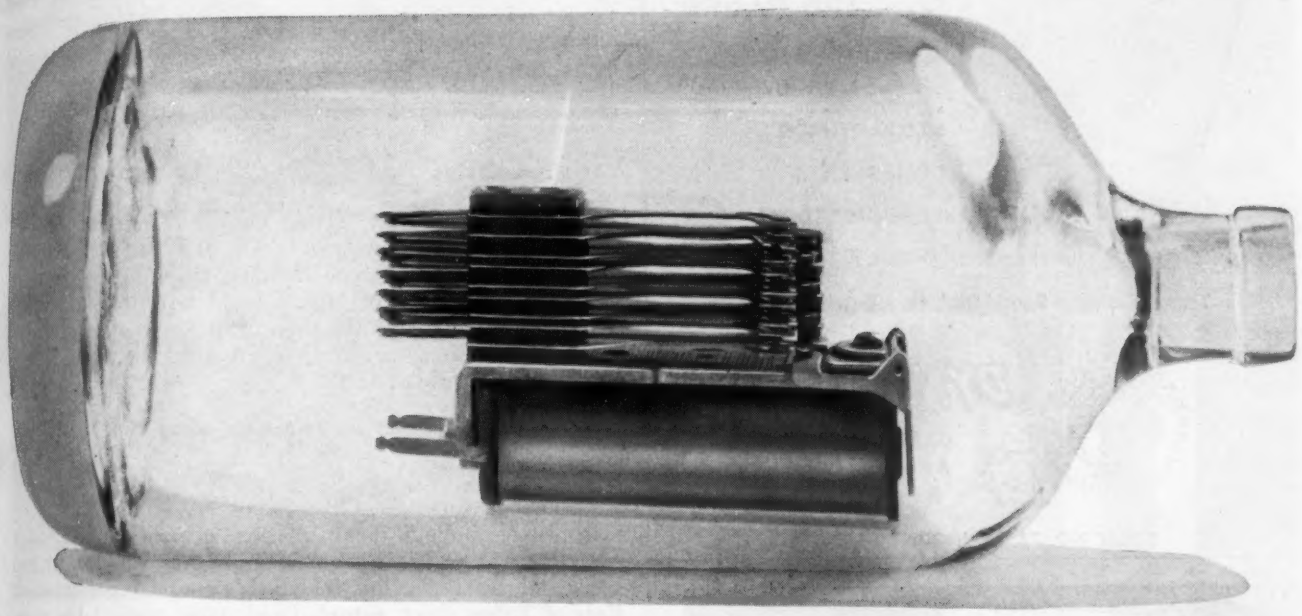

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facing an impossible situation

If you have a "hopeless problem" in automatic control, chances are that Automatic Electric can help you solve it in less time than it would normally take you.

What with our specialized experience in cooking up highly educated circuits and components for dial exchanges, we've earned a reputation for making ideas *work* automatically.

As an example: the AE Class B premium-quality telephone-type relay (illustrated) provides hundreds of millions of operations with unfailing contact reliability, and seldom needs maintenance. For this reason alone, it is probably the most inexpensive relay you can use where infallibility is essential.

As a support to your design skill, AE relays and stepping switches are custom-made to your precise engineering specifications. They're also available wired and assembled into complete control packages—a job we can handle for you at low unit cost.

For more information, write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1702-E on *Relays for Industry*.

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WORTH FILING

Fluid Connectors

Sixteen page catalog covers a basic line of fluid, self-sealing, quick disconnect couplings. Advantages of the connectors are described as minimum pressure drop, positive, reliable disconnecting and connecting, light weight, and broad range size and materials. Special section contains a table of condensed seal recommendations for fluids such as: aircraft fuels, exotic fuels, ethylene oxide, ammonia, nitrogen, coolants.

Source: E. B. Wiggins Oil Tool Co., Inc.
Los Angeles, Calif.

For Your Copy: Write No. 800 in Box on Inquiry Card

Terminal Strips

Twelve page brochure, "Guide Book To Terminal Strips," contains detailed drawings, tables and sample ordering diagrams on standard type terminal strips made up from various combinations of lugs. Special type terminal strips with any number or combination of lugs, any size or shape, made to individual specifications are available.

Source: Mandex Mfg., Co., Inc.
Chicago, Ill.

For Your Copy: Write No. 801 in Box on Inquiry Card

Plastic Parts

Sixteen page bulletin details plastic stock shapes and molded fabricated parts available in Teflon, Nylon, Delrin and other industrial plastics. Included are specs for standard sizes of Teflon sheet, extruded rod, tape, cementable tape, extruded tubing, molded bars and cylinders, as well as various types of filled Teflon T.F.E. and fusion welded Teflon. Specs are also given for Chemiseal nylon rod, slab, film, sheet, tubing and pressure tubing.

Source: Garlock Electronics Products, Garlock, Inc.
Palmyra, N.Y.

For Your Copy: Write No. 802 in Box on Inquiry Card

Strain Gage Transducers

Thirty-two page catalog contains concise descriptions of pressure transducers, linear and angular accelerometers, load cells, amplifiers, power supplies, bridge balances, strain gages and force/displacement transducers. Easy-to-read selection charts keyed to instrument ranges facilitate selection for specific requirements. Tables of conversion factors for pressure, force, linear acceleration, temperature, angular velocity, plane angles and weight are included for quick reference.

Source: Statham Instruments, Inc.
Los Angeles, Calif.

For Your Copy: Write No. 806 in Box on Inquiry Card

Computer Resolvers

Sixteen page monograph describes the characteristics of computing resolvers. Such definitive properties as function error and axis error are explained along with techniques of measurements. Described are basic tests that yield enough data for both system calculation and competitive evaluation.

Source: Theta Instrument Corporation
Saddle Brook, N.J.

For Your Copy: Write No. 804 in Box on Inquiry Card

NO POTS AT ALL

V44 - the new, ultra-stable, all-electronic digital voltmeter

No longer must you trim decade or amplifier gain potentiometers to make accurate, high-speed measurements with an all-electronic digital voltmeter. The new transistorized NLS V44 has *no pots at all* in its decade circuits because of ultra-stable electronic switches . . . *no pots at all* in the amplifier because amplifiers are used only within the feedback loop, where amplifier drift becomes inconsequential. Here is the speed you need — 3 milliseconds per reading — for measuring high-speed transient data . . . for multi-channel data logging. Contact NLS for complete information.

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NEW GYRO TEST

Next month we're publishing an authoritative article on testing gyro drift rate without using expensive turntables. The method, which can test gyros in place in a missile, aircraft or system package, will be of special interest to navigation systems designers and manufacturers who do not have complete gyro test facilities, or who should check gyro performance under system operating conditions.

The article will aid gyro test personnel in understanding new gyro acceptance tests under prepaartion by Massachusetts Institute of Technology, to be issued by the Military. It explains the tests, proves their validity and evaluates them in comparison with turntable methods.

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For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, enter the appropriate number of the item on the Inquiry Card.

Language Translator 728

Technical bulletin describes the various types and techniques of code conversion and the relative merits of different numerical codes which may be employed by the design engineer. A discussion of the theory of numerical codes is also included. Hermes Electronics Co., Cambridge, Mass.

Temperature Sensors 689

Thermocouple temperature sensors for use up to 4000 F are of the non-cooled and cooled types to measure liquid, solid and gaseous temperatures. Product information report includes data on temperature-emf relationships, time response characteristics and temperature limits of materials. Aero Research Instr. Co., Inc., Chicago, Ill.

Potentiometers 710

Technical data on potentiometers in a series of data sheets describes new 2-meg. translatory and protractatap potentiometers with precise operation, high reliability and extreme accuracy Accuracy, Inc., Waltham 54, Mass.

Ball Bushing 620

Two page bulletin describes newly developed ball bushing that is interchangeable with sleeve-type bushings in existing dies without modification of the punch holder. Unlimited travel permits die to be used in a press regardless of stroke. Thomson Industries, Inc., Manhasset, N.Y.

Hi-Temp Laminates 233

Bulletin describes 2 high-temp industrial laminated plastics for use at temperatures up to 500°F. Both types are available in tube form for special requirements. Synthane Corp., Glendale, Cal.

Felt for Electric Motors 383

Technical and application data, to help designers get the most out of felt, including typical designs for bearings and seals, descriptions of various properties and treatments available to improve the characteristics of felt comprise bulletins describing the important characteristics of felt for electric motor design. The Felters Co., Boston 11, Mass.

Photoelectric Tape Reader 419

Employing a printed armature motor, photoelectric tape reader needs no brakes and clutches of any kind to stop. Bulletin on the unit outlines in detail the operation of the reader and provides a complete listing of performance specifications. Photocircuits Corp., Glen Cove, N.Y.

Switches With Gold Contacts 645

Three series of basic subminiature switches with gold contacts offer a variety of designs for milli-volt, milli-amp dry circuit switching applications. Gold contacts are said to provide trouble-free switching throughout a long life. Mechanical characteristics and electrical ratings are included in four page data sheet. Minneapolis-Honeywell Reg. Co., Freeport, Ill.

Autopilot Input Simulator 63

Flight control systems which receive their input signals from synchros or resolvers may be tested for steady-state accuracy by means of a new rack-mounted instrument, called the system error bridge. Angular inputs, accurate within 20 sec.of-arc, may be dialled into the autopilot. The device is said to replace vertical gyroscopes and magnetic compasses for testing purposes. Theta Instrument Corp., Saddle Brook, N.J.

Constant-Current Supply 63

Technical bulletin describes the simple external connection required to convert programmable power supplies from volage- regulated to current-regulated output, and explains the method employed for control. Electronic Measurements Co., Inc., Eatontown, N.J.

Tolerance Ring 63

A corrugated open ring made of hard steel serves as a wedging shim between a shaft and its mating part, or a housing and its related part. Advantages claimed for the Star Tolerance Ring include: allowance for wider tolerances; provides for self-aligning, shock-absorbing, easy assembly and frequent disassembly; eliminates effect of temperature variations, key and keyways. Roller Bearing Co. of America, West Trenton, N.J.

Silicon Stabistors 63

Spec sheet includes performance curves for silicon stabistors. Low dynamic impedance and controlled forward charasteristics make the units ideal for use in transistor bias circuits, low level clipping or in reference and regulator applications. Silicon Transistor Corp., Long Island, N.Y.

Solid Film Lubricants 63

Solid firm lubricants operate without deterioration when exposed to nuclear irradiation of the order of 1 x 10^7 up to 1 x 10^9 Roentgens at temperatures up to 550 F. Wear life properties after exposure are actually increased by over 30%. The dry film lubricants are also corrosion resistant and lubricate efficiently in temperatures from —65 to 1800 F. Friction and wear life properties meet MIL specs 25504. Catalog contains complete technical data. Electrofilm, Inc., North Hollywood, Calif.

Trigistors 64

How low-level logic operations and high-level output combine in a single circuit with trigistor is the subject of an application bulletin. Power drive for print-hammers, solenoids, magnetic clutches and brakes, relays etc. is successfully combined with logic operations on the micro-ampere level. Solid State Products, Inc., Salem, Mass.

Miniature Motors 57

Eight page brochure describes miniature ac and dc motors, blowers and electro-mechanical devices for the avionics, electronics and instrument industries. American Electronics Inc., Los Angeles, Calif.

Time Delay Relay 5

Catalog containing latest engineering data on thermal delay relay applications includes glossary of terms and typical circuit diagrams. A broad line of relays are broken down into separate sheets, giving time delay ranges and voltages. Thermal Controls, Inc., No. Arlington, N.J.

Thermistors 531

Technical catalog contains specifications and data on bead, rod, disc and washer thermistors and disc and washer varistors. It also lists designers' kits, experimentors' items, thermal conductivity cells, temperature sensor assemblies and "chopperettes". Catalog includes definitions covering common terminology used in the application of thermistors and varistors. Victory Engineering Corp., Union, N.J.

Electrical Connectors 532

Power and control connectors for underwater service and ground support equipment are described in a 8-page bulletin. Basic design concept is one of homogeneous or unitized construction throughout, using resilient elastomeric compounds in the entire connector body. Resulting connections are said to equal or exceed all the electrical and mechanical properties of the cable itself. Joy Mfg. Co., St. Louis, Mo.

Servomotor Gearheads 534

400 cycle servomotor gearheads, 2 47/64" in length and weighing six ozs, are offered in over 1000 ratios—from 5:1 to 78125:1. Data on backlash, torque, housings and bearings includes performance curves and a circuit diagram. Guidance Controls Corp., Hicksville, N.Y.

Potentiometer Transducers 535

Four page bulletin provides specification data on potentiometer transducers. Units covered are for pressure, motion, altitude, weight, flow, indicating, recording and controlling. H. E. Sostman & Co., Cranford, N.J.

Testing Instruments 541

16 page catalog contains brief descriptions of 77 testers. Units are grouped under the following headings: abrasion testers; biological & scientic equipment; flammability-ignition tester; production, control and research equipment; thermal conductivity dielectric units; and thickness compression and recovery gages. Custom Scientific Instruments, Inc., Kearny, N.J.

Adjustable Speed Drives 543

Easily controlled and programmed, adjustable speed controls insure 1% to 2% regulation without tachometer feedback to automatically drive machine tools and special purpose machinery. Highly sensitive static feedback control automatically resets to follow an unlimited number of input signals to change speed or mode of operation. Speed changes, acceleration, deceleration, precision slowdown, precision shaft rotation stop, and dynamic braking and reversing are easily sequenced. Electronic Controls Inc., Stamford, Conn.

Quartz Crystal Transducers 544

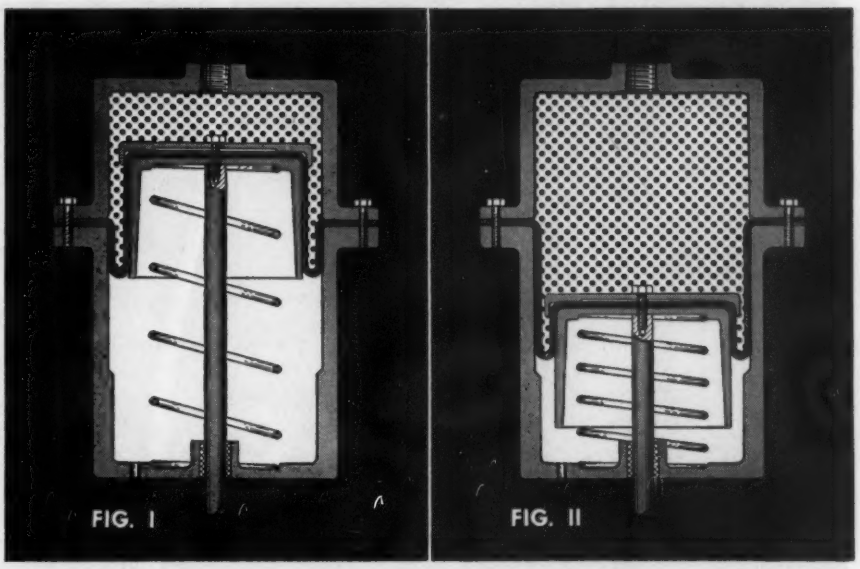
In addition to describing the range, sensitivity, and construction of natural quartz crystal transducers, a brochure highlights their unique characteristics for precisely measuring numerous physical phenomena such as pressure, force and vibration. A section describes associated electronic equipment including piezo-calibrators, amplifier-calibrators, low-noise cables, manual selector switch and complete indicator or transducer systems. Kistler Instrument Corp., No. Tonawanda, N.Y.

High Voltage Power Supplies 646

Eight page bulletin describes main components in the broad range of single and dual high voltage power supplies. Specification data for selection of the correct unit is included. Victoreen Instrument Co., Cleveland, Ohio

Servo Amplifier Motor 647

Bulletin contains engineering information on a high-grain, dc to ac servo amplifier with matched impedance motor. Operational principles and special features for various applications are described. Thermo Electric Co., Inc., Saddle Brook, N.J.



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The Bellofram Rolling Diaphragm provides ultrasensitive response in hydraulic or pneumatic devices where frictionless, long-stroke action in small-diameter configurations is required . . . and where flex life of millions of cycles is necessary.

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8. Compatibility with practically all environmental gases or fluids.
9. Automatic de-icing action.
10. Free positioning with complete relaxation at any point in its stroke.
11. Does not require close machine finish tolerances on pistons and cylinders.
12. Freedom from abrasive wear.
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14. Excellent temperature stability, from —85°F. to 550°F. (from —120°F. to 700°F. in some cases).

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Cylinder bore diameters from .25 to 12 in.

Extended range of stroke (.01 to 12 in.).

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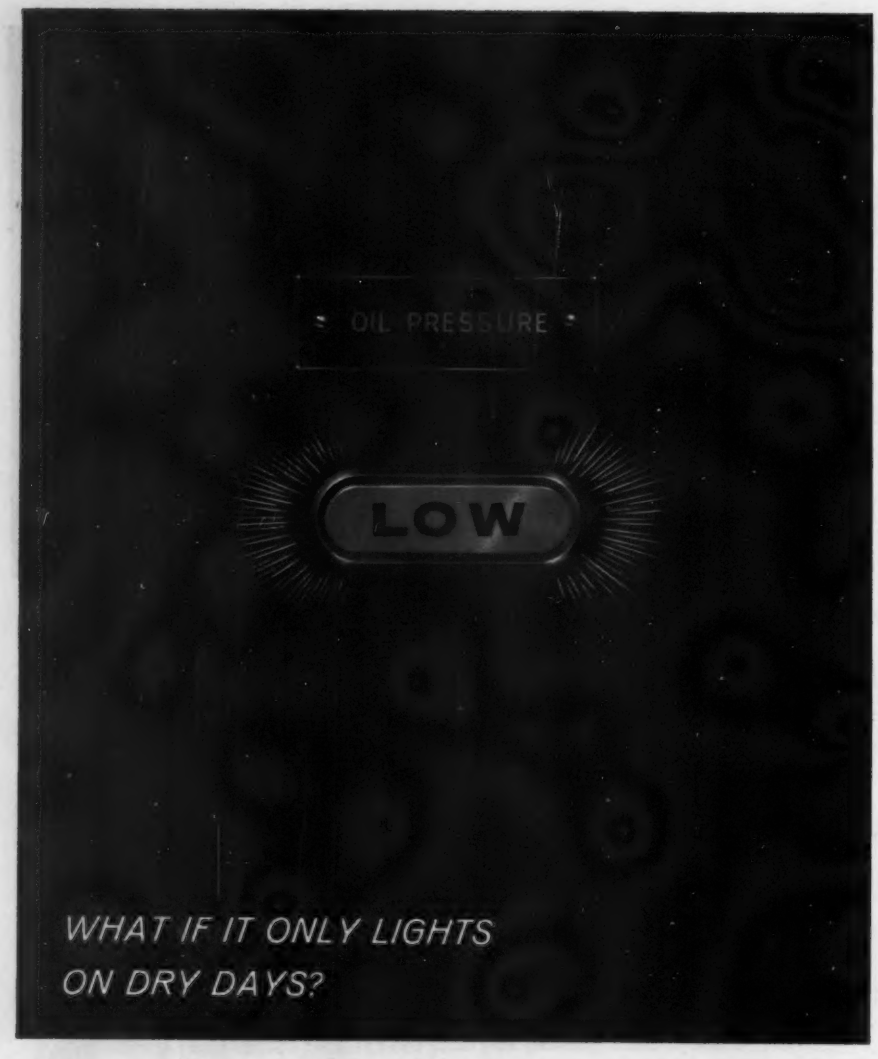


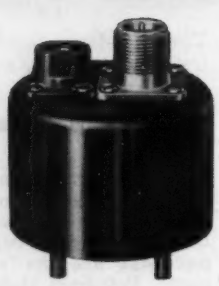
Pressure switches that only sound the alarm on dry days are small comfort when the weather gets soggy.

The *one* way to be sure about a pressure switch is to test it through the whole range of operating requirements . . . not just at 0% humidity or just at room temperature.

Take Model 6547 shown at right which serves in many ways . . . cabin pressure alarm, landing gear position signal, electronic equipment operation, acting parallel to an altimeter. This pressure switch has a calibration accuracy of 20 mm Hg from −65° F to 250° F, 0 to 100% humidity, with an actuation range of 2,000 to 20,000 and 15,000 to 70,000 feet. It weighs only 5½ ounces.

Do what we did. Get one and run it through six weeks of testing over the *entire* range of your operating requirements.

Or you can save yourself six weeks by examining our own test data on a full line of pressure switches for the type that meets your needs best. Call Mr. Charles Colt at Consolidated Controls, Bethel, Conn. Phone Pioneer 3-6721, DDD Code 203.



Inches of Water to Hundreds of Atmospheres

Model 6547 shown above is one of more than 300 pressure switches available from Consolidated Controls for missile, aircraft and nuclear applications. Working pressures range from 10" of water to 10,000 psi at ambient temperatures from −65°F to 1000°F. Standard models for

- high vibration
- differential pressures
- hydraulic
- miniaturized applications
- high temperature

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CIRCLE NO. 83 ON INQUIRY CARD

Electronic Cables 630

Folder details a wide variety of basic materials available for conductors, insulations, shields, jackets, and armors for electronic wire and cables. Cutaway sections show construction of cables for electronic controls and check-outs, instrument probes, airframes, missiles, satellites, nuclear system controls and other instrumentation. Sequoi Wire & Cable Co., Redwood City, Calif.

FHP Motors 631

Small ac special application motors, in fractional horsepower ratings between 1/100 and 1/3 are described in an eight page bulletin. Different models result from four frame sizes, three types of mounting, three pole speeds and four types of motor design. Robbins & Myers, Inc., Springfield, Ohio

Miniature Circuit Breakers 632

Standard current ratings, release coil impedances, typical time delay curves, mounting and outline dimensions are given on miniature magnetic circuit breakers. A complete list of definitions and explanation of gang assemblies and instantaneous acting overload breakers is included. Airpax Electronics Inc., Cambridge, Md.

Plugs and Connectors 633

Six page brochure describes integrally molded-on electrical plugs and connectors, patch cords for digital and analog computers and custom moldings. All contacts, solder joints and wire ends are embedded in a solid molded body of high impact material. Components Mfg. Serv. Inc., W. Bridgewater, Mass.

Capacitors 634

Construction, uses and performance characteristics of tantalum foil electrolytic capacitors are described in a bulletin. Meeting Mil-C 3965, the capacitators are either polar or non-polar type, plain or etched foil with all capacity tolerances and vibration grades. Temperature range is from —55 to 85 C without voltage derating. Units carry a dc surge rating of 116% of rated working voltage. Standard Pressed Steel Co., Jenkintown, Pa.

Potentiometers 641

Complete specifications catalog of single turn, wire-wound precision potentiometer from ½" dia. to 3" dia. describes size and dimensions, mechanical requirements and electrical properties. Maurey Instrument Corp., Chicago, Ill.

Electric Ovens 642

In addition to the standard basic ovens, catalog covers a variety of special designs for die heating, rubber curing, baking chemicals, glass annealing, aluminum treating, etc. Also discussed are the advantages of folded-and-formed ribbon-type resistance heating elements which allow evtremely accurate process control over a wide temperature range. They seldom, if ever, need replacement under normal operating conditions. Trent, Inc., Phila., Pa.

Pressure Transducers 643

Designed for missile and operational aircraft applications in low pressure ranges, small lightweight pot pressure transducers will stand 100 g shock. Gage and absolute types are available in nine standard pressure ranges within zero to 100 psi. High dc output eliminates the need for impedance-matching and signal amplifying in most applications. Consolidated Electrodynamics Corp., Pasadena, Calif.

Precision Instruments 644

Eight page catalog contains brief details and summary specifications for precision electronic instruments, components, synchros and servo motors, servo equipment and telefacsimile equipment. A precision rms decade voltmeter has a wide voltage range of one mv to 1100 volts, frequency range of five to 100 cps. Measurement accuracy is 0.05% even at low supply frequency. Muirhead Instruments Inc., New York, N.Y.

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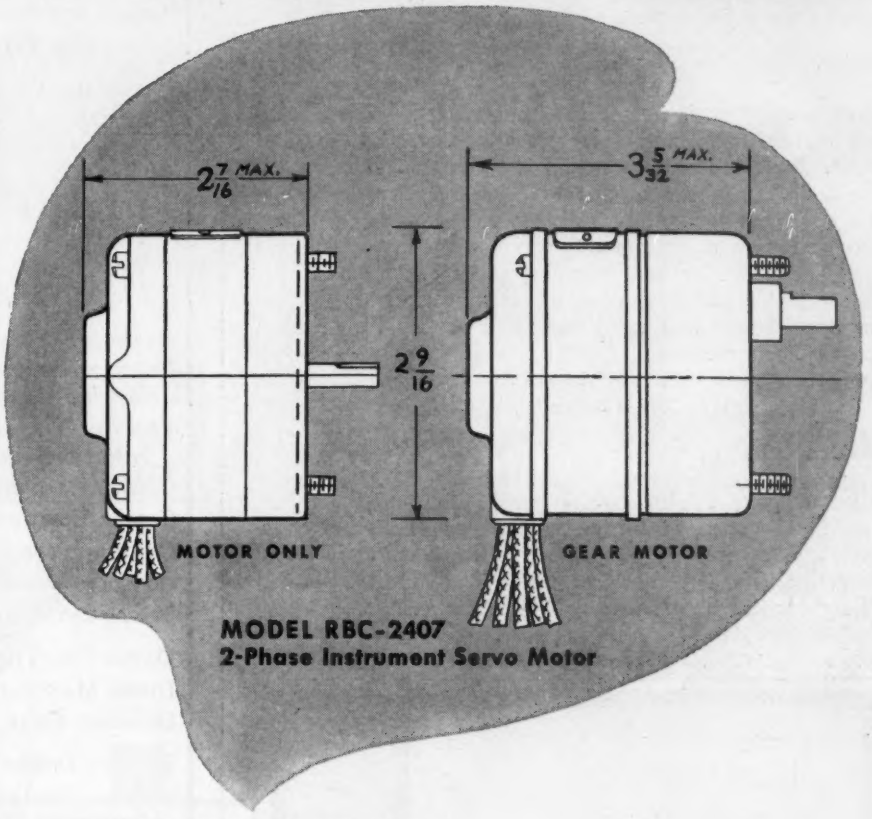

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Source: General Electric, Schenectady, N.Y.

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Metals

Fourteen-page revised brochure describes solid and clad base metals, solid and clad precious metals, thermostat metals, electrical contacts and various other industrial metals. Included for the first time are sections describing solid and clad gold and silver for industrial applications, silver cadmium oxide contacts and contact materials, clad seamless tubing for heat transfer, precision parts for the semiconductor industry, platinum-group metals for industrial applications and solid and clad metals for electron tube applications.

Source: Texas Instruments Inc., Attleboro, Mass.

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Plastics

Sixty-four page catalog covers plastic sheets, rods, tubes, films, blocks and flat tubings. Listed are available sizes, weights, color ranges, textures, specifications, grades and prices. Included is comparison table of chemical, electrical and mechanical properties of 14 plastics families.

Source: Cadillac Plastic & Chemical Co., Detroit, Michigan

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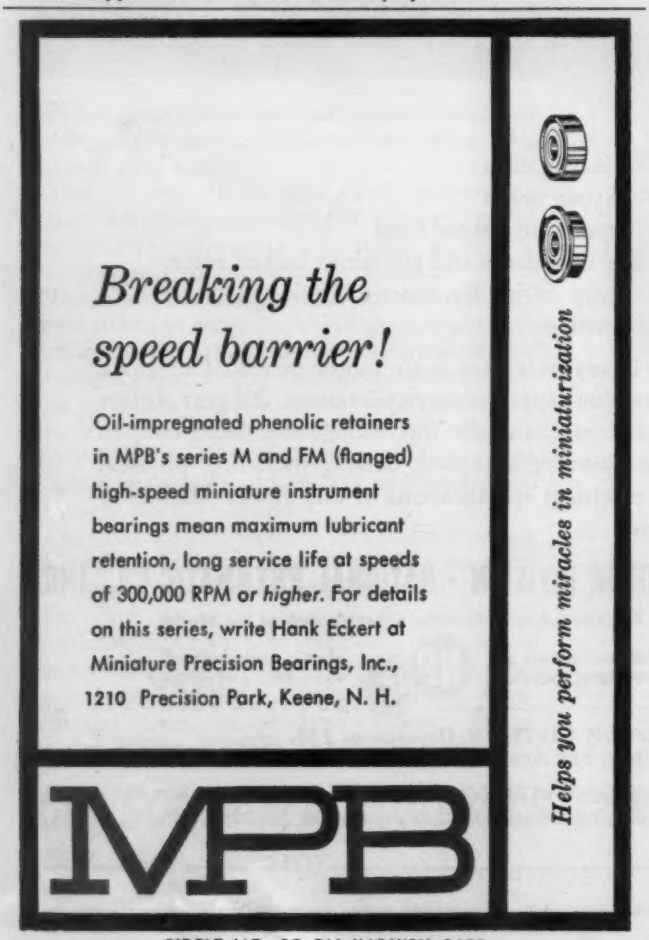
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